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RUN-OFF FROM THE DRAINED PRAIRIE LANDS OF SOUTHERN LOUISIANA

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INTRODUCTION

While the draining of low-lying lands by means of pumps has long been practiced in parts of England and Holland, the application of this means of securing drainage for lands in the United States is a comparatively recent development. A small amount of pumping of drainage water had been done on a number of sugar plantations in southern Louisiana before the middle of the last century, but these pumping plants were crude affairs. About 1908 the work of reclaiming the Gulf coast marsh lands by means of drainage pumping was actively started. Gradually, modern machinery was introduced until by the end of 1915 about 125,000 acres of land were under pump. Prior to the starting of this work there existed no very complete nor accurate data as regards the amount of water these plants would be called on to pump each year. Neither were there records as to what the maximum capacity of the plants should be. While there were available some more or less fragmentary records of the operation of drainage pumping plants in Europe, the conditions of climate, rainfall, and soil in the United States are so different that European records were not considered to be of practical value. The capacities of the earlier pumping plants were based upon very rough approximations. They were more often too small than too large. The need for information on this subject soon became so apparent that in 1909 Drainage Investigations, Office of Experiment Stations, United States Department of Agriculture, undertook the task of collecting such data. The work was actually begun in the month of April, 1909, by Messrs. W. B. Gregory and A. M. Shaw, who made the necessary measurements of the capacity of four drainage pumping plants and started a set of records of operation. Late in 1909 the work of carrying on these investigations was assigned to the writer and has been continued under his charge to the present time. The work of rating the capacity

of the pumps in the drainage plants has been extended along with records of operation of the same plants until the records now cover 10 drainage districts. At the end of each year progress reports have been issued giving the results collected. It is now proposed to summarize these reports in one publication.

OBJECT OF THE INVESTIGATIONS

The primary object of this work has been to establish the relation existing between the rainfall and the amount of water that it is necessary to pump from typical areas of land in order to secure a degree of drainage that will allow the growing of the ordinary field crops. When this relation is once determined, the rainfall data furnished by the Weather Bureau will enable the engineer to design adequate and economical drainage pumping plants for the swamp lands of the Gulf coast.

The records also disclose the total amount of pumping necessary in each year. In this paper the term "run-off" is used to denote the water that is removed by the pumps; in the tables the run-off is expressed as a uniform depth of water (in inches) over the drained area.

DESCRIPTION OF DISTRICTS

The districts on which the investigations are being carried on vary in area from 647 acres to 7,500 acres, and the various details of soil, crops, surface slope, and character of the drainage channels and levees, are different on each district. Therefore it is believed that it will be of advantage to describe each district, giving a brief summary of conditions prevailing during each year covered by the records.

SMITHPORT PLANTING COMPANY TRACT—AREA, 647 ACRES

This tract adjoins the village of Lockport, Lafourche Parish. The land from which this plantation was reclaimed is typical of the open, grass-covered prairies that lie to the west of Bayou Lafourche. The surface slopes from the bayou to the low swamps in the rear. About half the area under consideration was originally covered with the water of Lake Fields to a depth of 1 to 3 feet. The humus or muck on this tract varied in depth from 18 inches on the higher portions to perhaps 8 inches in the lake bed. A considerable portion of the muck in the higher portions of the area is overlain by a layer of river silt about 10 inches thick. Silt of the same character forms the subsoil of the whole district. The total fall in the surface from the higher, or "front" portion to the lower side is about 4 feet. The ditch system is very complete, and the small field ditches go entirely across the area directly into the reservoir canal which skirts one side. The reservoir capacity up to the end of 1912 was 0.40 inch of water, and that of the pumping plant 1.10 inches, over the area drained. Thereafter the reservoir

capacity was increased to 0.50 inch by further dredging. Except for a few short periods the entire area was well drained during the time covered by the records. During the early part of the period covered by the records the levees on this district were subject to a heavy seepage when the stage of the water was high on the outside. Later the levees were increased in size and the seepage was reduced greatly.

CONDITIONS DURING 1909.—During this year about 25 per cent of the area was in cultivation. The remainder was covered with grass and weeds. The portion of the land cultivated was well drained throughout the year. Some of the lowest land near the reservoir was flooded for a short time during the heavy rainfall of September 20, but this was due to the fact that the tropical hurricane which accompanied the rainfall interfered with the proper operation of the machinery.

CONDITIONS DURING 1910.—About 65 per cent of the land was cultivated, and the entire area was well drained. The year was deficient in total rainfall and in heavy storms. The early part of the year was exceptionally dry.

CONDITIONS DURING 1911.—The cultivated area was increased to 75 per cent and drainage was maintained. Some quite heavy rainfalls occurred. Toward the end of the year fairly heavy rainfall coming at a time of low evaporation raised the water outside the district so that very heavy seepage came through the levees. The records for December (Table I) do not represent normal relations as between rainfall and amount pumped; they were not included in obtaining averages for the period.

CONDITIONS DURING 1912.—The cultivated area amounted to 85 per cent. A continuation during January of the high stage of water outside the district caused the amount of water pumped to be greatly above normal, and a recurrence of this stage of outside water in June and July, and again in December, caused the pumping for the year to be excessive. The averages for the tract exclude the above months.

CONDITIONS DURING 1913.—During this year the entire tract was brought under cultivation for the first time. The water level in the main canal was held unusually low, and drainage was complete at all times, with no flooding. During the year nearly the entire length of levee received further addition of material, and its ability to keep out seepage water was thereby much increased. It does not appear from the records that any great amount of seepage water entered the district except during the first part of January. Although the run-off during the month of October was greater than the rainfall, most of the rainfall came the last few days of September and was not pumped during the same month. By taking the two months together the percentage of rainfall in the run-off is about 75 per cent—not an excessive amount for such heavy rainfall at that time of year.

TABLE I.—*Rainfall and run-off on the Smithport Planting Company tract, June, 1909, to September, 1915, inclusive*

Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pump ran.	Rain fell.
1909.	*Ins.*	*Ins.*	*P. ct.*	*Days.*	*Days.*
June	10.63	4.20	39.5	12	12
July	2.19	.46	21.0	2	7
August	8.62	3.40	39.5	6	12
September	5.61	2.71	48.3	7	7
October	2.90	1.62	55.8	4	3
November	2.00	.00	.0	0	5
December	5.26	3.44	65.4	10	11
Total	37.21	15.83	42.5	41	57
1910.					
January	2.15	1.26	58.6	7	4
February	4.15	1.42	34.2	7	8
March	1.00	.47	47.0	3	2
April	.12	.00	.0	0	2
May	3.29	.12	3.6	1	7
June	5.43	.17	3.1	1	11
July	10.39	4.96	47.7	13	17
August	3.15	.28	8.9	4	9
September	3.84	.58	15.1	7	6
October	2.68	.37	13.9	3	8
November	2.52	.25	10.0	3	4
December	2.76	.95	34.4	6	6
Total	41.48	10.83	26.1	55	84
1911.					
January	1.50	.93	62.0	5	2
February	1.73	.66	38.2	5	5
March	2.05	.57	27.8	4	4
April	6.44	3.02	46.9	9	7
May	3.08	1.40	45.4	7	7
June	2.29	.00	.0	0	8
July	7.50	1.97	26.3	16	15
August	10.87	5.15	47.4	16	15
September	3.71	.82	22.1	7	12
October	4.07	1.97	48.4	8	6
November	4.81	2.14	44.5	6	5
December	6.51	7.21	110.7	19	10
Total	54.56	25.84	47.4	102	96
1912.					
January	3.85	6.83	177.4	16	8
February	3.78	2.61	69.1	7	5
March	3.66	2.10	57.4	7	7
April	3.62	1.87	51.6	7	10
May	6.09	4.65	76.3	13	6
June	7.73	10.24	132.0	24	9
July	5.39	6.90	128.0	19	11
August	5.50	1.53	27.8	5	10
September	1.99	.24	12.1	1	3
October	2.18	.75	34.4	2	4
November	3.72	1.64	44.1	8	3
December	11.35	10.98	96.7	22	15
Total	58.86	50.34	85.5	131	91

Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pump ran.	Rain fell.
1913.	*Ins.*	*Ins.*	*P. ct.*	*Days.*	*Days.*
January	4.31	4.11	95.3	12	6
February	2.60	1.76	67.7	7	7
March	4.57	3.27	71.6	10	7
April	2.68	1.05	39.2	3	4
May	3.49	1.69	48.6	3	4
June	2.77	.22	7.9	1	7
July	10.78	4.68	43.5	10	11
August	6.47	4.14	62.2	9	9
September	14.26	6.34	44.4	10	15
October	3.53	7.45	211.0	13	7
November	2.14	1.24	58.0	2	3
December	2.41	1.78	74.0	6	6
Total	60.01	37.73	62.9	86	86
1914.					
January	1.34	1.15	85.8	3	3
February	5.71	2.98	52.2	6	4
March	3.38	3.38	100.0	9	4
April	1.43	.75	52.4	3	3
May	1.43	.43	30.1	2	3
June	1.95	.49	25.1	2	2
July	10.01	4.81	48.5	10	15
August	6.06	3.71	61.2	12	9
September	4.22	2.04	48.3	7	5
October	2.31	2.28	98.7	4	2
November	10.01	7.73	77.2	10	7
December	4.25	6.39	150.4	18	5
Total	52.10	36.14	69.4	86	62
1915.					
January	5.03	4.68	93.0	12	5
February	5.56	3.35	60.3	10	6
March	2.23	2.41	108.0	6	4
April	.00	.00	.....	0	0
May	2.58	.52	20.2	2	4
June	1.44	2.36	164.0	4	4
July	5.96	3.31	55.5	5	9
August	5.70	2.87	50.3	11	10
September	2.11	.31	14.7	1	3
October [a]	.....	.....	.....	.....	.....
November [a]	.....	.....	.....	.....	.....
December [a]	.....	.....	.....	.....	.....
Total	30.61	19.81	64.7	51	45
Averages for period (5.91 years)	50.8	26.2	51.6	76.5	79.2

[a] Records omitted, as they do not represent normal conditions.

CONDITIONS DURING 1914.—During this year the whole of the tract was under cultivation. With the exception of one period in April, when the district was flooded with water from the adjacent highland, it was well drained throughout the year. The rainfall and amount pumped during the above-mentioned period are omitted from Table I, as they do not represent normal conditions. In November a very heavy rainfall occurred, which gave the highest rate of pumping, due to rainfall, so far experienced on this district (Table I). While the reservoir was full for

3 days, no flooding of the surface occurred. A small amount of seepage entered the district during the last day or two of November and the first 10 days of December. Continued drainage and cultivation had so compacted the humus or muck which originally covered the surface on this district that the top soil was no longer greatly different in appearance from that encountered on the average cultivated fields on near-by plantations. Careful examination would still show the origin of the top soil, but it had lost all of its turfy characteristics.

CONDITIONS DURING 1915.—The entire area was cultivated and well drained until the end of September. The early part of the year was very dry, but abnormally heavy rains occurred in the last few days of September and the early part of October and caused overflow from the adjoining highland. This water was pumped out, but it is not included in the records, as it did not represent typical conditions.

WILLSWOOD PLANTATION—AREA, 2,600 ACRES

This plantation, located about 10 miles above New Orleans, fronts on the Mississippi River. The soil along the river front is of a characteristic sandy nature, becoming finer grained as the distance from the river bank increases. A tract of about 800 acres which makes up the rear of the plantation was at one time a part of the adjacent wet prairie. It was formerly covered with a light growth of willows and the usual prairie grass. The humus or muck was originally 3 or 4 feet deep, although at present, after about 19 years of cultivation, it is well decayed and compacted, making a rather heavy soil. The total fall in the land surface from the front to the rear of the plantation is about 10 feet.

All the small field ditches run from the front to the rear of the plantation, down the greatest slope; but frequent larger cross ditches intercept these field ditches at intervals of about a quarter of a mile and carry the water to larger canals, which run in the same direction as the field ditches. The main reservoir along the rear of the plantation carries the water to the pumping plant. The capacity of the pumping plant was about 1.50 inches of water on the area drained per 24 hours. The capacity of the reservoir was about 0.40 inch of water over the area.

The levee was built around this district from material taken from immediately inside of the levee, and yet no appreciable amount of water seeps into the reservoir canals. All water is pumped out promptly from this district, and the reservoir canal is kept nearly empty, in readiness for heavy rains.

In the early spring of 1911 the area was increased by the addition of about 200 acres of river-front land, enlarging the total area to 2,600 acres. The pumping plant capacity was thus reduced to 1.40 inches per 24 hours, but, as the reservoir canals were later cleaned out, the reservoir capacity became about 0.42 inch. Except for high-water conditions in

the summer of 1912, the drainage of this tract has not been interrupted, and, as the total area was constantly in cultivation, no comment will be made as to conditions each year. The area is typical of all river-front plantations, except that it has a relatively larger area of drained, low, flat land in its rear. (See Table II.)

TABLE II.—*Rainfall and run-off on Willswood plantation, June, 1909, to December, 1915, inclusive*

Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pumps ran.	Rain fell.
1909.	*In.*	*In.*	*P. ct.*	*Days.*	*Days.*
June	10.42	5.13	49.2	9	15
July	5.55	.65	11.7	3	15
August	7.62	3.25	42.6	9	12
September	6.42	2.58	40.2	5	5
October	4.06	.83	20.4	5	5
November	1.46	.50	34.2	4	4
December	6.79	3.99	49.9	10	10
Total	42.32	16.93	40.0	45	66
1910.					
January	2.14	.92	43.0	4	3
February	3.51	1.71	48.7	7	6
March	2.44	1.37	56.1	4	2
April	1.31	.00	.0	0	2
May	4.36	.73	16.7	2	6
June	5.11	.61	11.9	3	7
July	7.59	2.90	38.2	9	18
August	3.82	.17	4.4	1	8
September	3.72	.43	11.6	3	8
October	2.15	.14	6.5	1	9
November	2.93	.63	21.5	3	5
December	4.00	1.97	49.2	8	8
Total	43.08	11.58	26.9	45	82
1911.					
January	1.33	1.03	77.4	4	2
February	1.56	.22	14.1	2	4
March	5.45	2.35	43.1	7	4
April	11.82	7187	66.6	14	7
May	3.20	2.50	78.1	8	4
June [a]	4.14	.36	8.7	2	4
July [a]	3.69	1.16	31.4	5	0
August [a]	6.02	.59	9.8	3	16
September [a]	2.18	.53	24.3	4	9
October	1.96	.11	5.6	1	3
November	3.57	1.08	30.3	6	3
December	7.40	5.61	75.8	13	10
Total	52.32	23.41	44.7	69	75
1912.					
January	4.41	4.94	112.0	12	6
February	2.82	1.48	52.4	8	4
March	6.22	4.92	79.1	12	6
April	9.68	6.93	71.6	14	8
May	10.96	7.28	66.4	13	7
June	.....	.....	.....	.....	.....
July	.....	.....	.....	.....	.....
August	.....	.....	.....	.....	.....
September	.....	.....	.....	.....	.....
October	1.93	.22	11.4	2	4
November	2.51	.91	36.2	4	2
December	9.69	97.74	79.9	16	11
Total	48.22	4.42	71.4	81	48

Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pumps ran.	Rain fell.
1913.	*In.*	*In.*	*P. ct.*	*Days.*	*Days.*
January	6.36	5.20	81.8	13	8
February	2.46	1.51	61.4	5	6
March	4.02	2.46	61.2	10	8
April	5.64	3.23	57.3	6	4
May	3.63	2.40	66.2	5	6
June	2.00	.10	5.0	1	6
July	4.39	.52	11.8	2	9
August	4.62	.00	.0	0	7
September	11.81	7.37	62.3	13	13
October	3.86	2.99	77.5	8	5
November	1.58	.63	39.9	2	1
December	1.15	.67	58.3	3	3
Total	51.52	27.08	52.6	68	76
1914.					
January	1.02	.39	38.2	2	2
February	5.92	2.19	37.0	5	4
March	4.51	3.03	67.2	8	5
April	3.73	1.52	40.8	4	4
May	.88	.14	15.9	1	3
June	2.30	.19	8.3	1	6
July	3.84	.....	.....	.....	13
August	3.32	.....	.....	.....	12
September	6.70	1.44	21.5	3	6
October	2.24	1.08	48.2	5	3
November	3.71	1.53	41.2	5	3
December	4.08	3.54	86.8	7	5
Total	42.25	15.05	35.6	41	56
1915.					
January	6.00	5.76	96.0	13	4
February	5.95	4.95	83.1	11	6
March	1.07	2.78	260.0	7	3
April	.00	.24	.....	1	0
May	1.88	.00	.0	0	6
June	2.67	.00	.0	0	6
July	7.09	1.54	21.7	5	5
August	7.69	1.49	19.4	5	10
September	8.73	1.76	20.2	2	4
October	10.33	14.23	137.3	12	5
November	.38	.81	139.5	4	3
December	2.06	.68	33.0	3	4
Total	54.05	34.24	63.4	63	56
Average for period (6.25 yrs.)	53.40	26.05	48.9	65.6	75.4

[a] No record.

LAFOURCHE DRAINAGE DISTRICT NO. 12, SUBDISTRICT NO. 1—AREA 835 ACRES

This district lies about 2 miles southwest of Raceland, mostly in typical wet prairie land of the Lafourche section. It has a natural slope toward the pumping plant. The highest portion of the district is perhaps 3 feet above mean low water in the surrounding waterways and the lowest portion about 2 feet. About three-fourths of the district was originally covered with a depth of from 1 to 2 feet of turfy humus or muck, while the remainder was a cypress swamp which had been burned over and the trees finally killed and leveled. Pumping was started about 1908 and has since been continuous. In 1913 the inside reservoir canals were relocated and made larger, the levees reinforced, and the old pumping plant replaced by a new one. The present plant, when working at best economy, has a capacity sufficient to remove a depth of 1.70 inches of water from the entire district per 24 hours. The reservoir capacity is about 0.40 inch of water over the district. The district is completely ditched and practically all cultivated. As parts of the area have been cultivated for five years, the muck has been greatly compacted and is at present only a few inches thick; it is quite a heavy soil as compared with the original condition.

CONDITIONS DURING 1915.—During the early part of the year there was evidently considerable seepage entering the district. After the first three months the weather was dry, and the evaporation took up practically the entire rainfall. During the month of October the district experienced very heavy rains, and the pumping was greatly increased because of seepage; therefore the records for the month are omitted from the averages. (See Table III.)

NEW ORLEANS LAND COMPANY TRACT—AREA 1,255 ACRES

This tract lies just within the northern city limits of New Orleans and fronts on Lake Pontchartrain. It is bordered on the west by the New Basin Navigation Canal and on the east by the outfall canal from the city pumping station 7. The water on three sides is slightly above sea level and is perhaps, on the average, about a foot above the average land surface of the district. The tract was originally a part of the swamp that bordered Lake Pontchartrain and was covered with a rather heavy growth of trees, cypress being the predominating variety. This growth had been cut down when the record started, but only about 100 acres were cleared and cultivated. The remainder was allowed to grow up in weeds and brush. The soil is soft and spongy on the surface, with a high percentage of vegetable matter. The subsoil is the usual Sharkey clay to a depth of from 6 to 10 feet; this is underlain by almost pure sand which undoubtedly allows a considerable seepage into the district. The effect of the seepage on the run-off totals for each month is more noticeable during the winter months than at other times, especially if the

winter rainfall be light. The seepage is doubtless nearly constant so that during the months of small rainfall it forms a relatively large portion of the total run-off. The drainage water is collected by a few large canals (not many small ditches were cut when records were started) and discharged by gravity into the city drainage canal. The water was measured by means of a weir and a water register placed in the outfall canal.

CONDITIONS FROM 1909 TO 1912, INCLUSIVE.—During these years the area of cleared and cultivated land was increased so that by the end of 1912 the area well drained was about 400 acres. The remainder of the area was not completely ditched. Such water as entered the main canals was discharged promptly.

CONDITIONS DURING 1913.—The area ditched and cultivated or improved as residence property was increased during the year to about 500 acres. Owing to further ditching the area tributary to the main outfall canal was estimated at 1,180 acres after January 1, 1913. On October 25 the weir was placed farther down the main outfall canal, thus increasing the total area above the weir to 1,255 acres.

CONDITIONS DURING 1914 AND 1915.—During these years the area of drained and improved land was gradually increased. By the end of 1915 nearly all the area had been ditched and about 75 per cent had been cleared. About 300 acres had been improved with residences and sidewalks. A part of the remaining cleared land was under cultivation.

The amounts of water appearing in the column headed "Run-off" in Table IV represent the actual water that found its way into the main canals. These canals were of such size that water was discharged very quickly after it had once reached them. It was only during very extreme drouths that a small amount of water at least was not flowing over the weir. If the same area had been drained by a pumping plant, the run-off during these days of such small flow would have been combined in two or three days in the month, and the total quantity of water pumped would have been less, as the evaporation from the open canals would have been greater. This is shown by the fact that on the pumping districts the water in the canals is often lowered by evaporation alone during dry times.

UNIT NO. 1, POYDRAS, LA.—AREA, 2,500 ACRES.

This district fronts on the Mississippi River about 20 miles below New Orleans, near the little town of Poydras, St. Bernard Parish. About 500 acres of the front portion were originally covered with a light growth of timber; the remainder was a part of the open grass-covered prairie typical of that section of the State. The top 3 or 4 feet of the soil in the prairie have a very high percentage of vegetable material, and would be classed as muck. This muck, however, is not as turfy as that originally on the Smithport tract or the districts around Raceland, and seems to have a higher percentage of river silt. The subsoil is Sharkey clay.

The district was first inclosed and the pumps started in March, 1912. At that time not many of the field ditches were cut. The work of cutting the ditches was carried on during the summer months and was finished in October or November. This district has a very complete system of drainage canals, spaced ¼ mile apart, although the usual spacing is ½ mile. The levee is of ample cross section and does not allow any seepage to enter the district. The pumping-plant capacity is approximately 1 inch per 24 hours, and the reservoir capacity is approximately 0.75 inch.

CONDITIONS DURING 1912.—As stated above, the land was not well drained until toward the end of the year. The results for 1912 are interesting chiefly because they show the amount of water to be removed from this kind of soil when it first drained. There were no ponds or other bodies of water within the district. The rainfall records for 1912 are those of the nearest station, New Orleans, distant about 20 miles. While in detail these records differ materially from those that would have been obtained on the tract, the total for the period covered is probably not greatly in error.

CONDITIONS DURING 1913.—During this year the entire area was drained by the pumping plant. The water was held about 4 feet below the surface and no flooding occurred. Owing to the soft nature of the soil, the small field ditches were quite badly choked with soft mud and did not carry the water very rapidly to the canals. During dry periods it was observed that the level of the ground water was considerably below the bottoms of these small field ditches; this indicated subdrainage of the soil by the canals which were spaced only ¼ mile apart. The rainfall records for 1913 were taken from the rain gage on the tract. About 400 acres of that part of the district bordering the river and about 100 acres of the prairie land were in cultivation in 1913.

CONDITIONS DURING 1914.—During the entire year the tract was well drained and the water held about 4 feet below the surface. In March two periods of heavy pumping occurred. In each period the plant operated at full capacity for a little over 24 hours without stopping. The water, however, did not approach nearer than 2 feet to the surface of the ground. About 400 acres of that part of the district bordering the river and about an equal amount of the prairie land were in cultivation. All the land that was cultivated was well drained by field ditches which had been cleared of soft mud and vegetation. The field ditches of the remainder of the tract were still in very poor condition.

CONDITIONS DURING 1915.—The amount of cultivated land in 1915 and the general conditions of field ditches and drainage canals were the same as in the previous year. While the first two months of the year were rather above the average in amount of rainfall, the remainder of the spring and the summer were very dry, except that one heavy rainfall occurred in June. At the end of September this district was flooded by a combination of excessive rainfall and water coming in from the adjacent land;

normal conditions were not restored until the end of the year. (See Table V.)

GUEYDAN DRAINAGE DISTRICT, SUBDISTRICT NO. 1—AREA 7,500 ACRES

This district lies in the southwestern part of the State, and its natural features are quite different from those of the districts previously described. The land was taken from the typical wet prairie of southwestern Louisiana. While the surface was covered with a grass similar to that found in the aforementioned districts, the muck is very much shallower and more turfy in character. Before drainage the average depth was somewhat less than a foot. The muck is underlain by a clay subsoil that is very solid and impervious. The surface slope of the district is from north to south, toward the pumping plant, and totals about 2 feet in 3 miles. The area was first inclosed and the pumps started in March, 1912. As the subsoil was solid, the water was lowered very rapidly without damage to canal banks. The work of cutting the field ditches was begun in December, 1911, and was finished during the following summer months. The main drainage canals are spaced ½ mile apart.

The percentages of the rainfall in run-off during the first three months of operation were not calculated, as all the original surface water was not drained out until about the first of June. There were no bodies of open water inclosed in this district. On August 23, 1912, the area of the district was increased from 5,600 to 6,500 acres. For this latter area the capacity of the pumping plant was 1.25 inches per 24 hours and the reservoir capacity was 0.88 inch.

CONDITIONS DURING 1913.—During 1913 this tract experienced heavier precipitation than had any of the districts up to this time. It is apparent from the run-off records (Table VI) that considerable seepage entered the district during the early part of the year, and again in the last four months. While this was sufficient to affect the monthly totals, it does not make a relatively great difference in the maximum run-off for any particular storm. The amount of seepage per day depended on the height of the water on the outside of the district. Very little water appears to have seeped through the levees during a time when the water was not well over the surface of the surrounding undrained prairie. The entire seepage into the district was through a section of levee about 2,000 feet long which crossed a very soft area of land where the muck was from 5 to 15 feet deep and where the levee had not been built of good material nor to full height and cross section. As the drainage canal was immediately inside this section of the levee, the head against this soft material was often 4 to 7 feet. Cultivation was started on the higher parts of the area, and by the end of April 500 acres were plowed. Early in July the area of the district was increased to 7,500 acres by the addition of 1,000 acres of raw prairie land which had been ditched.

CONDITIONS DURING 1914.—Early in 1914 the area of this tract tributary to the pumping plant was decreased to 6,500 acres. Whenever the stage

of water in the surrounding prairie was over the general surface there was considerable seepage through the weak section of levee. This is shown in the records for the first five months and the last two months of the year. During the other five months the water in the outside prairie was low, and seepage practically ceased. The total area cultivated was about 600 acres. Of this amount about 300 acres were in rice. Water was taken from the interior drainage channels to irrigate the rice land, and this further decreased the amount of water pumped out of the district during the months from June to August, inclusive.

CONDITIONS DURING 1915.—During the early months of 1915 the amount of water pumped, relative to the rainfall, was very heavy. However, by the middle of May the weak section of levee had been so much strengthened that very little seepage water entered. During the summer months a little over 1,000 acres of rice were grown in the district, and water to irrigate the rice was all taken from the inside drainage channels. It was owing to this practice that only a small amount of water was pumped during the summer months. On December 1 the area was again increased to 7,500 acres by the addition of the 1,000 acres which were drained during a part of the year 1913. As the two months previous to the time this land was again brought into the district had been very dry, no pumping was necessary to remove water from the new land. (See Table VI.)

LITTLE WOODS TRACT—AREA, 6,943 ACRES

This tract lies along the southern shore of Lake Pontchartrain, about 2 miles east of the New Orleans Land Co. tract. The frontage on the lake is about 7 miles. The width at the eastern end is about 2 miles and at the western end 1½ miles. Most of the surface was originally covered with a heavy growth of grass, only a small percentage of the area having been timbered. The surface was but a few inches above the mean lake level, and, except for a few small ridges and shell mounds, the tract was at one time subject to overflow whenever the lake was at high tide. A considerable depth of turfy humus or muck covered the entire area; the range in depth was from 1 foot along the lake shore to as much as 10 feet in the portion about a mile back from the lake. The average depth of muck was perhaps 5 feet.

Reclamation work was started in 1908, and in the fall of that year a pumping plant was erected with a maximum 24-hour capacity of 0.48 inch. Although a very small percentage of the canals necessary to drain the tract had at that time been constructed, the pumping plant was started in October, 1908. The construction of the canals and ditches was carried on during the time records of rainfall and pumping were kept. At times part of the tract was dammed off from the pumping plant, so that the relation between rainfall and amount pumped is not comparable to the results from the other districts already described. By the spring of 1912 about 600 acres of the tract had been drained with small field ditches, but in the remainder of the area only a few of the larger canals

had been excavated. No rain gages were kept on this district during this period, so that the rainfall records from surrounding stations necessarily must be used. In view of the above features, it is not considered that the records of amount pumped during these earlier years would be of value for comparison with those of other districts. Therefore the records (Table VII) are given only for the period beginning January, 1913.

CONDITIONS DURING 1913.—During 1913 quite extensive changes were made. The construction of the main drainage channels was carried forward rapidly. The spacing of the main channels is ½ mile with the usual field ditches leading into them. A main canal carries the water to the pumping plants. A second pumping plant was constructed during the summer and placed in operation toward the end of the year. From the beginning of the year until May 1, the entire area was tributary to the old pumping plant; after that date the area was reduced to 2,400 acres, the remaining land being dammed off and not drained. From September 22 until October 29 water was allowed to run over these dams from the undrained portion into the canals of the drained portion. On October 29 these dams were closed, after which the old plant drained the 2,400 acres, and the new plant drained the remaining 4,543 acres. The records given in Table VII show the data from the old plant alone. The 2,400 acres drained by the old plant were almost completely ditched by the end of the year, and about 200 or 300 acres were in cultivation.

CONDITIONS DURING 1914.—Until the middle of May the district was still divided between the old and the new pumping plants. The 2,400 acres drained by the old plant were very completely drained and the canals were cleared of a great deal of soft mud and vegetable matter. The cutting of the field ditches in this portion was nearly finished. After the middle of May the two portions of the district were connected and all drainage water pumped by the new plant. The 24-hour capacity of the new plant is about 1.25 inches of water over the entire area of 6,943 acres. The canals in the newer portion of the district were deepened and widened, and the cutting of the field ditches was nearing completion. In the portion of the district near the old pumping plant, where cultivation was being started, the water was held very low for the entire year; while in the newer portions where ditching operations had not started, the drainage was not nearly so complete. The capacity of the completed and enlarged reservoir canals was now nearly an inch of water from the entire area. By the end of 1914 the area ditched had been increased to 5,400 acres, and 1,680 acres were in cultivation. (See Table VII.)

CONDITIONS DURING 1915.—The entire area was drained during this year by the new pumping plant. The early part of the year was marked by heavy rainfall, but after March the spring and summer months were unusually dry. The ditched area was gradually increased during the year to about 6,500 acres and the cultivated area to about 4,500 acres. The records were interrupted toward the end of September by the admis-

sion of some outside water. Normal conditions were restored in November and records resumed on December 1. (See Table VII.)

DES ALLEMANDS POLDER NO. 1—AREA 1,880 ACRES

This district includes a portion of the town of Des Allemands, in Lafourche Parish, and borders on Bayou Des Allemands. The land from which the district was taken is typical of that lying along Bayou Des Allemands. It has an elevation of from 1 to 2 feet above the mean water level in the bayou, and a large percentage of the land is made up of firm silt ridges with a very thin layer of muck on the surface. The muck was originally from 8 to 12 inches deep and was quite turfy. With the exception of a few scattering trees on the ridges, the tract was covered with a heavy growth of the natural prairie grass.

The reservoir canals extend across the district with a spacing of about 2,000 feet and have a storage capacity of about 0.35 inch. The pumping plant capacity under average conditions is about 0.75 inch per 24 hours. Pumping was started on this district in October, 1912, and was continuous thereafter. Ditching operations were commenced at the same time and carried on throughout the year 1913, so that by the end of the year about one-third of the area was completely ditched. Cultivation was started early in 1913, and by the end of the year 250 acres were cultivated.

During the months of January and February, 1913, a section of levee about 300 feet long allowed a considerable amount of seepage water to enter the district. This seepage had to be pumped out each day. In the latter part of February this defective spot was repaired. After that, except for a period of about a month in the latter part of September and the early part of October, it is considered that no appreciable amount of seepage entered the district.

CONDITIONS DURING 1914.—During 1914 about half the tract was completely ditched and drained. The remaining portion was partly drained with ditches having four times the usual spacing. The reservoir canals needed cleaning, and their poor condition made it necessary to pump much oftener than would otherwise have been the case. The water had to be lowered to near the bottom of the canal at the pumping plant before the effect was felt at the end of the district remote from the plant. If the canals had been in good condition, the number of days on which the pumps operated would have been much decreased, although the total amount pumped would have been little different. In the latter part of November a rainfall of 5.45 inches occurred in about three hours. This caused the pumping plant to operate at full capacity for about three days. The canal was full at the station for about 24 hours, after which it lowered very rapidly. If the canals had been in good condition, they would have delivered much more water to the pumping plant than it was able to handle, while with the canals in poor condition the pump was capable of taking the water away faster than it flowed to the pump. The area under cultivation during the year was increased to about 600 acres.

CONDITIONS DURING 1915.—During the first three months of the year the rainfall was heavy and the water level in the surrounding canals outside the district was from 1 to 2 feet above normal. As a result considerable seepage entered the district, and the amount pumped during these months was above normal. The following three months were very dry and no pumping occurred. The summer months were about normal as to percentage of rainfall pumped. At the end of September the records were rendered abnormal by the entrance of outside water into the district, and records were not resumed until the end of the year. The amount of cultivated land was increased to 800 acres. (See Table VIII.)

JEFFERSON DRAINAGE DISTRICT NO. 3—AREA, 5,000 ACRES

This district is located about 25 miles southwest of New Orleans on Bayou Barataria. One entire side of the district is bounded by the above bayou, and two other branch bayous border the ends of the district. The remaining side is bordered by a canal dug for the purpose of obtaining material for the levee. About three-fourths of the levee on this area is located on the solid banks of the bayous; consequently little, if any, seepage enters the district. Except a very narrow strip of solid clay land along the bayous, the soil of this district is the usual prairie muck. The muck originally varied in thickness from 1 to 4 feet. Most of the surface was covered with the ordinary prairie grass. Except for a small elevation of perhaps 2 feet along the bayous, the surface of the district is level and has an elevation of 1 foot or less above average water in the surrounding bayous. The inside canals are quite extensive and are so spaced that the longest field ditch is but 2,000 feet in length. The storage capacity of the canals is about 0.60 inch.

Ditching was started early in 1913, and by the end of the year nearly the whole area had been drained with ditches at a spacing of 220 feet. Pumping operations were started in February, 1913, and the record of operations was started on March 12. Except for a small amount of land along the bayou, no cultivation was done in 1913. Under average conditions the capacity of the pumping plant is 1.25 inches.

CONDITIONS DURING 1914.—During the year the district was all drained. The cutting of the field ditches was completed, and all canals were cleaned and deepened. After the canals were cleaned it was not necessary to run the plant on as many days as was formerly the case, since the water could be more completely taken out of all the canals and it was not necessary to stop the plant and wait for the water to flow to it. While three heavy rains occurred during the early part of the year, the ground was unusually dry in each case before the rain, so that no very heavy pumping was necessary; in fact, the plant was not operated at full capacity during the entire year. By the end of the year 200 or 300 acres of land were under cultivation.

CONDITIONS DURING 1915.—The entire area was well drained throughout the year. Very heavy rainfalls occurred in September and October,

but the pumping plant removed all drainage water promptly. The cultivated area was about 250 acres at the beginning of the year and was gradually increased to about 600 acres by the end of the year. (See Table IX.)

LAFOURCHE DRAINAGE DISTRICT NO. 12, SUBDISTRICT NO. 3—AREA, 2,250 ACRES

This district is located about 3 miles southwest of Raceland in the typical prairie land of the Lafourche section. It has a natural slope toward the south to Lake Fields. The highest part of the district is perhaps 3 feet above mean low water in the lake and the lowest part is about at mean low water level. The whole of the area was originally covered with a layer of turfy muck from 1 to 3 feet thick. The subsoil is the usual Sharkey clay. The levees around the district were built from material taken from the outside of the drained area and have been reenforced by further work. Except at times of very high water in the surrounding waterways and canals outside the area, it is believed that very little seepage enters the district. The interior drainage system is quite extensive, but requires some smaller collecting ditches to take the water from the small field ditches. The storage capacity of these drainage canals is about 0.50 inch.

This area was first inclosed in March, 1910. Nearly all the field ditches were cut during that year, and the remaining ditch work was finished by the early part of 1912. Pumping operations were started in 1910, and, with an addition to the plant made in 1912, the capacity under average conditions is about 1.15 inches per 24 hours. Drainage has been maintained continously since 1910. The records of operations were started in December, 1912.

Cultivation was started on this district early in 1910, and the area gradually increased until in 1913, the first year of records, about 800 acres were in cultivation. During 1913 the entire district was well drained, and conditions in general were practically normal.

CONDITIONS DURING 1914.—The entire district was well drained during the year. While some very heavy rains occurred, the plant was of ample capacity. The rain that gave the heaviest run-off occurred in the latter part of November on a very wet soil. In the first 24 hours of operation the pumps lowered the water 1.5 feet in the canals, and at the end of 40 hours they were stopped, as the water had been lowered 4 feet. The total pumping for the year was quite close to the amount to be expected normally.

During the year nearly all the field ditches were placed and maintained in good condition, and about 2,000 acres of the district were in cultivation.

CONDITIONS DURING 1915.—During the entire year, except October, the district was well drained. During that month some water entered the district from outside, and the records were interrupted. With the exception of the first two months of the year, the spring and summer

months were very dry and little pumping was done. All the field ditches were cleaned out, and the entire area was cultivated. (See Table X.)

TABLES OF RAINFALL AND RUN-OFF

In the tables (I–X) the monthly and yearly summaries for the various districts are given. At the end of each of the tables is a statement of the average amounts of rainfall, run-off, etc., for the period covered by the records for that district, proper corrections having been made for such times as the records were temporarily suspended or the conditions as to rainfall or run-off were abnormal. As each district has local characteristics, it is considered that any figure obtained by taking a general average of the values for all of the districts would be of no special significance. However, certain of the districts and years have been selected as being typical of conditions prevailing on lands reclaimed from the wet prairies of southern Louisiana. These districts and years are as follows: Lafourche Drainage District No. 12, Subdistrict No. 3, 1913, 1914, 1915; Unit No. 1, Poydras, La., 1914, 1915; Des Allemands Polder No. 1, 1914; Jefferson Drainage District No. 3, 1914, 1915; Gueydan Drainage District, Subdistrict No. 1, 1915. Where the period during 1915 did not cover an entire year, the yearly totals have been corrected proportionately before averaging. The results are as follows: Average rainfall, 48.95 inches; average run-off, 21.56 inches; average number of days on which pumps operated, 90.

The above annual rainfall is somewhat below the mean annual rainfall for New Orleans, but it is believed that the percentage of rainfall appearing as run-off (44 per cent) is not greatly in error for average conditions. With this percentage and a mean annual rainfall of 56 inches, the amount of run-off to be expected per year under average conditions would be 24.6 inches.

TABLE III.—*Rainfall and run-off on Lafourche Drainage District No. 12, Subdistrict No. 1, April, 1914, to December, 1915, inclusive*

Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pumps ran.	Rain fell.	Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pumps ran.	Rain fell.
1914.	*In.*	*In.*	*P. ct.*	*Days.*	*Days.*	1915—Continued.	*In.*	*In.*	*P. ct.*	*Days.*	*Days.*
April	5.20	3.39	65.2	3	2	April	0.00	0.00	.....	0	0
May	2.85	.95	33.3	5	4	May	1.61	.00	.0	0	2
June	4.63	.64	13.8	2	4	June	1.66	.00	.0	0	3
July	8.00	3.14	39.3	7	7	July	5.09	2.51	49.4	3	3
August	7.50	1.94	25.9	5	8	August	6.99	.00	.0	0	12
September [a]	[b]7.00	.....	.....	.....	[b]4	September	2.10	.00	.0	0	3
October	.00	.44	.....	2	0	October [c]	.....	.....	.....	.....	.....
November	10.90	8.03	73.6	10	3	November	1.55	.32	20.6	1	3
December	3.32	5.37	161.7	14	4	December	1.30	.00	.0	0	1
Total	42.40	23.90	56.4	48	32	Total	33.23	20.57	61.75	42	36
1915.						Averages for period (1.58 years)	47.7	28.0	58.7	56.7	42.9
January	4.40	7.06	160.6	15	2						
February	6.30	6.65	105.5	14	4						
March	2.23	4.03	180.8	9	3						

[a] Averages do not include September, 1914. [b] Not included in total.
[c] The record for October, 1915, is omitted.

TABLE IV.—*Rainfall and run-off on New Orleans Land Company tract, June, 1909, to December, 1915, inclusive*

Month.	Rainfall.	Run-off.	Rainfall in run-off.	Rain fell.
1909.	*In.*	*In.*	*P. ct.*	*Days.*
June	2.15	0.62	28.8	5
July	6.72	.88	12.3	13
August	5.34	1.21	22.7	14
September	1.40	.24	17.0	6
October	3.44	1.42	41.3	5
November	1.26	.66	52.4	5
December	7.43	4.95	66.6	9
Total	27.74	9.98	36.0	57
1910.				
January	.90	.84	93.3	3
February	4.14	(a)	(a)	7
March	3.21	2.22	69.2	2
April	1.10	.76	69.0	2
May	7.25	1.16	16.0	7
June	6.39	1.07	16.7	12
July	11.41	5.35	46.9	22
August	7.10	1.82	25.6	7
September	5.50	(a)	(a)	8
October	1.74	(a)	(a)	8
November	2.06	.82	39.8	4
December	3.12	1.73	55.4	9
Total	53.92	15.77	29.3	91
1911.				
January	1.90	2.43	127.9	3
February	1.49	.96	64.4	5
March	5.19	3.73	71.9	3
April	12.56	8.81	71.4	10
May	2.39	3.27	135.8	7
June	6.17	1.16	18.8	9
July	6.84	3.04	44.4	14
August	7.63	2.09	27.4	17
September	4.08	1.13	27.7	12
October	2.41	.76	31.5	5
November	4.18	.88	21.0	8
December	7.38	4.43	60.1	15
Total	62.22	32.69	52.5	108
1912.				
January	4.48	5.60	125.0	10
February	3.70	2.34	63.2	6
March	9.32	8.22	88.2	8
April	8.41	7.59	90.2	12
May	4.73	2.99	63.2	9
June	2.52	1.25	49.6	10
July	8.37	1.79	21.4	16
August	6.99	.89	12.7	17
September	2.88	.62	21.5	10
October	1.72	.90	52.3	6
November	2.17	1.21	55.8	3
December	10.43	7.19	68.9	13
Total	65.72	40.59	61.9	120
1913.				
January	4.59	4.41	96.0	7
February	1.76	2.78	158.0	6
March	4.07	2.70	66.5	8
April	4.50	2.46	54.6	4
May	7.70	2.85	37.0	9
June	2.40	.79	32.9	9
July	6.33	1.91	30.1	17
August	6.61	3.25	49.2	11
September	10.92	7.02	64.3	12
October	5.41	3.41	63.0	7
November	3.02	.96	31.8	4
December	1.41	1.65	117.0	3
Total	58.72	34.19	58.2	97
1914.				
January	1.33	.87	65.4	2
February	5.91	1.78	30.1	4
March	4.76	4.07	85.5	7
April	3.84	3.03	78.9	5
May	1.57	.78	49.7	3
June	2.97	.22	7.4	5
July	7.70	2.70	35.1	9
August	8.75	3.27	37.4	14
September	7.89	4.92	62.4	10
October	.88	1.92	218.2	4
November	4.30	1.71	39.8	6
December	4.19	2.84	67.8	5
Total	54.09	28.11	52.0	74
1915.				
January	6.35	5.375	84.6	5
February	4.71	4.215	89.5	7
March	1.42	2.435	171.2	4
April	.04	.495	.....	1
May	4.51	.385	8.5	6
June	3.47	.865	24.9	3
July	8.21	3.360	40.9	8
August	6.60	2.440	37.0	8
September	2.70	.890	33.0	4
October	10.25	9.520	92.9	5
November	1.64	1.150	70.2	3
December	4.12	2.095	50.9	4
Total	54.02	33.225	61.5	58
Averages for period (6.33 years)	59.5	30.78	51.7	96

[a] Record omitted.

TABLE V.—*Rainfall and run-off on Unit No. 1, Poydras, La., March, 1912, to December, 1915, inclusive*

Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pumps ran.	Rain fell.	Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pumps ran.	Rain fell.
1912.	*In.*	*In.*	*P. ct.*	*Days.*	*Days.*	1914—Continued.	*In.*	*In.*	*P. ct.*	*Days.*	*Days.*
March	10.81	3.72	.....	20	10	March	6.54	5.33	81.5	17	4
April	8.62	1.96	.....	12	16	April	3.10	1.56	50.3	11	3
May	16.80	5.29	.....	24	12	May	.20	.17	85.0	2	1
June	4.11	1.34	.....	8	13	June	3.38	.10	3.0	1	7
July	7.58	6.20	.....	14	18	July	3.16	.12	3.8	1	4
August	4.93	1.10	.....	5	15	August	9.04	.42	4.6	3	14
September	3.84	1.49	.....	5	8	September	5.07	.97	19.1	6	4
October	2.47	1.66	.....	6	7	October	1.46	.53	36.3	4	2
November	2.50	.98	.....	4	5	November	4.51	.64	14.2	4	4
December	11.21	6.93	.....	21	18	December	4.00	3.23	80.8	11	4
Total	72.67	30.67	.....	119	122	Total	47.70	16.46	34.5	73	54
1913.						1915.					
January	5.71	4.52	79.0	18	10	January	6.96	5.82	83.6	17	5
February	2.82	4.81	170.0	16	8	February	3.70	3.17	85.7	14	5
March	6.55	2.82	43.0	16	10	March	2.02	2.62	129.8	10	4
April	6.04	3.34	55.3	18	4	April	.00	.00	.....	0	0
May	5.25	3.88	73.9	16	7	May	3.91	.34	8.7	2	4
June	3.91	.50	12.8	4	3	June	8.46	1.27	15.0	5	6
July	9.58	4.58	47.8	15	11	July	3.34	1.93	57.8	6	2
August	4.74	2.34	49.3	12	7	August	5.85	.73	12.5	5	7
September	9.48	6.21	65.5	17	9	September	1.90	.33	17.4	3	2
October	4.33	4.26	98.4	11	4	October [a]	.....	.....	.....	.....	.....
November	.57	.35	61.4	3	1	November [a]	.....	.....	.....	.....	.....
December	4.92	1.61	32.8	9	7	December [a]	.....	.....	.....	.....	.....
Total	63.90	39.42	61.7	155	81	Total	36.14	16.21	44.9	62	35
1914.						Averages for period (2.75 years)	53.7	26.2	48.8	105.2	61.5
January	0.89	0.76	85.4	5	1						
February	6.35	2.63	41.4	8	6						

[a] Records omitted.

TABLE VI.—*Rainfall and run-off on Gueydan Drainage District, Subdistrict No. 1, March, 1912, to December, 1915, inclusive* [a]

Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pumps ran.	Rain fell.	Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pumps ran.	Rain fell.
1912.	*In.*	*In.*	*P. ct.*	*Days.*	*Days.*	1914.	*In.*	*In.*	*P. ct.*	*Days.*	*Days.*
March	4.13	10.46	.....	14	9	January	0.55	1.83	333.0	13	5
April	2.45	6.85	.....	30	5	February	5.61	3.73	66.4	16	5
May	4.07	3.06	.....	31	3	March	3.56	3.33	93.5	19	8
June	10.09	5.04	50.0	25	9	April	8.77	8.64	98.5	18	6
July	6.13	5.65	92.1	23	8	May	4.45	3.61	81.1	16	5
August	7.45	2.34	31.4	20	13	June	3.00	.32	10.7	3	6
September	2.53	1.29	51.0	17	3	July	5.04	.14	2.8	2	13
October	2.45	.69	28.2	10	3	August	9.41	2.18	23.2	14	20
November	1.01	.23	22.7	4	3	September	4.45	1.91	42.9	13	9
December	11.40	7.65	67.1	22	9	October	2.84	1.92	67.5	10	7
Total	51.71	43.26	[b]56.0	196	65	November	8.30	6.30	75.9	21	9
						December	3.80	5.95	156.5	22	10
						Total	59.78	39.86	66.7	167	103
1913.						1915.					
January	4.45	5.35	120.0	28	4	January	3.37	8.00	237.5	23	8
February	3.80	4.21	111.0	24	8	February	3.13	3.31	105.8	15	6
March	3.30	2.60	79.0	13	3	March	2.11	2.60	123.1	12	2
April	5.30	2.81	53.1	12	2	April	.52	.58	111.4	4	2
May	2.90	1.01	34.8	6	4	May	5.72	.32	5.6	3	6
June	7.81	3.74	47.9	10	7	June	3.23	.23	7.1	2	3
July	13.63	5.35	39.3	16	11	July	11.46	3.46	30.2	6	7
August	4.65	2.10	45.1	12	9	August	10.11	3.52	34.8	7	5
September	16.60	7.13	43.0	17	12	September	.31	.59	190.3	2	2
October	9.70	17.82	183.8	29	12	October	2.46	.15	6.1	1	1
November	1.90	3.85	202.3	24	3	November	.75	.00	.0	0	1
December	3.00	3.58	119.2	23	9	December	6.60	1.45	22.0	3	4
Total	77.04	59.55	77.3	216	84	Total	49.77	24.21	48.6	78	47

[a] Owing to seepage, average figures for the entire period of record would not be typical; these averages, therefore, are omitted.

[b] Does not include March, April, and May, 1912.

TABLE VII.—*Rainfall and run-off on Little Woods tract, January, 1913, to December, 1915, inclusive*

Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pumps ran.	Rain fell.	Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pumps ran.	Rain fell.
1913.	*In.*	*In.*	*P. ct.*	*Days.*	*Days.*	1914.	*In.*	*In.*	*P. ct.*	*Days.*	*Days.*
January	4.40	5.56	122.0	31	8	June	4.30	0.28	6.5	17	7
February	2.10	3.33	158.5	28	8	July	7.20	1.18	16.4	27	16
March	5.30	3.40	64.2	26	8	August	8.40	2.66	31.7	25	13
April	3.50	1.58	45.2	25	3	September	2.80	1.20	42.9	21	4
May	4.40	1.44	32.7	8	8	October	2.00	1.03	51.5	27	3
June	3.45	1.13	32.6	6	10	November	3.90	1.40	35.9	26	7
July	2.87	.16	5.6	1	12	December	4.10	2.76	67.3	31	6
August	3.95	.31	7.8	2	8	Total	50.60	20.46	40.0	299	78
September	9.90	2.82	28.5	15	17	1915.					
October	3.27	2.83	36.6	28	6	January	7.60	6.16	81.1	31	7
November	1.90	.94	49.5	6	3	February	4.60	4.89	106.2	28	6
December	1.00	1.00	100.0	6	2	March	2.10	3.21	153.0	30	5
Total	46.04	24.30	52.8	182	93	April	.00	.34	.....	15	0
1914 (old plant).						May	3.20	.28	8.8	5	6
January	1.10	0.91	82.5	5	2	June	3.40	.43	12.6	9	6
February	6.40	1.78	27.8	8	6	July	7.30	3.39	46.5	27	6
March	4.90	6.13	125.1	22	7	August	6.50	1.38	21.2	21	8
April	4.80	3.88	80.8	18	4	September	2.10	.85	11.9	6	3
May [a]	.20	.43	215.0	6	1	October [b]	.....	.....	.....	.....	.....
Total	17.40	13.13	75.5	59	20	November [b]	.....	.....	.....	.....	.....
1914 (new plant).						December	6.00	4.06	67.7	29	7
January	1.10	1.10	100.0	24	2	Total	42.80	24.39	57.00	201	54
February	6.40	1.44	22.5	20	6	[c] Averages for period (1.83 years)	51.40	24.45	47.60	273	72.0
March	4.90	3.29	67.2	31	7						
April	4.80	3.27	68.1	26	4						
May	.70	.85	121.4	24	3						

[a] 12 days in May. [b] Records suspended. [c] Includes only the time that conditions were typical.

TABLE VIII.—*Rainfall and run-off on Des Allemands Polder No. 1, January, 1913, to September, 1915, inclusive*

Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pumps ran.	Rain fell.	Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pumps ran.	Rain fell.
1913.	*Ins.*	*Ins.*	*P. ct.*	*Days.*	*Days.*	1914.	*In.*	*In.*	*P. ct.*	*Days.*	*Days.*
January	3.50	2.97	84.9	24	6	October	0.90	0.60	66.7	10	2
February	2.16	3.18	147.0	22	6	November	6.75	3.39	50.2	12	3
March	4.20	2.62	62.3	21	7	December	3.70	4.85	131.1	27	5
April	2.15	1.86	86.5	13	3	Total	45.70	25.83	56.5	177	39
May	3.58	1.31	36.6	11	5	1915.					
June	1.88	.34	18.1	3	2	January	7.21	6.78	94.0	28	7
July	9.40	2.56	27.2	10	6	February	6.15	8.26	134.2	28	5
August	2.80	2.27	81.1	26	4	March	2.15	3.84	178.5	17	3
September	9.60	5.15	53.7	23	9	April	.00	.00	.0	.0	0
October	4.46	5.57	125.0	26	5	May	1.00	.00	.0	.0	1
November	1.64	1.02	62.3	11	3	June	.00	.00	.....	.0	0
December	2.00	2.01	100.0	17	3	July	5.00	1.49	29.8	6	3
Total	47.37	30.86	65.1	207	59	August	4.70	1.28	27.2	9	2
1914.						September	2.20	.29	13.2	4	3
January	1.00	.92	92.0	17	1	October [a]	.....	.....	.....	.....	.....
February	5.70	2.86	50.2	17	4	November [a]	.....	.....	.....	.....	.....
March	4.75	3.99	84.0	25	4	December [a]	.....	.....	.....	.....	.....
April	4.60	3.52	76.5	22	2	Total	28.41	21.94	77.2	92	24
May	.80	.49	61.3	11	2	Averages for period (2.75 years)	44.2	28.6	64.7	173.0	44.4
June	2.40	.45	18.8	5	2						
July	2.60	.43	16.5	5	3						
August	8.20	2.49	30.4	12	7						
September	4.30	1.84	42.8	14	4						

[a] Averages do not include October, November, and December, 1915.

TABLE IX.—*Rainfall and run-off on Jefferson Drainage District No. 3, March, 1913, to December, 1915, inclusive*

Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pump ran.	Rain fell.	Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pump ran.	Rain fell.
1913.	*Ins.*	*Ins.*	*P. ct.*	*Days.*	*Days.*	1914.	*Ins.*	*Ins.*	*P. ct.*	*Days.*	*Days.*
March	6.21	3.00	48.3	13	13	November	4.30	2.09	48.6	8	6
April	5.82	4.03	69.2	14	4	December	3.83	2.60	67.9	11	4
May	4.58	3.23	70.5	13	5	Total	48.16	26.46	55.0	104	58
June	1.29	.80	62.0	8	5	1915.					
July	6.01	1.26	21.0	8	14	January[a]					
August	4.94	2.66	53.7	13	7	February	4.41	1.79	40.6	7	6
September	13.03	7.51	57.6	19	14	March	2.74	3.55	129.6	10	4
October	5.22	3.70	71.0	15	4	April	.75	.44	58.6	3	1
November	1.00	.90	90.0	8	3	May	3.35	.00	.0	0	3
December	1.50	1.44	96.0	9	5	June	2.44	.22	9.0	1	3
Total	49.60	28.53	57.5	120	74	July	6.07	1.24	20.4	6	6
1914.						August	3.10	.37	11.9	2	5
January	1.06	1.19	112.3	8	1	September	6.76	.57	8.4	2	4
February	8.07	3.70	42.5	13	6	October	9.48	7.84	82.7	20	5
March	6.00	7.78	129.7	19	2	November	1.40	.36	25.7	2	1
April	4.42	3.10	70.1	12	2	December	4.11	1.80	43.8	8	6
May	2.58	.92	35.7	5	4	Total	44.61	8.18	40.7	61	44
June	2.94	.57	19.4	3	3	Averages for period (2.75 years)	51.8	26.6	55.8	103.7	64.0
July	6.79	1.03	15.2	6	11						
August	3.79	.74	19.5	5	9						
September	3.95	2.19	55.4	10	7						
October	.43	.55	128.0	4	3						

[a] Averages do not include January, 1915.

TABLE X.—*Rainfall and run-off on Lafourche Drainage District No. 12, Subdistrict No. 3, December, 1912, to December, 1915, inclusive*

Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pump ran.	Rain fell.	Month.	Rainfall.	Run-off.	Rainfall in run-off.	Pump ran.	Rain fell.
1912.	*Ins.*	*Ins.*	*P. ct.*	*Days.*	*Days.*	1914.	*Ins.*	*Ins.*	*P. ct.*	*Days.*	*Days.*
December	11.56	6.79	58.7	24	14	September	6.14	1.70	27.7	6	11
1913.						October	.45	.00	.0	0	3
January	5.88	4.77	81.2	21	5	November	10.61	5.37	50.6	11	6
February	2.85	2.27	79.6	11	4	December	3.83	2.76	72.1	15	6
March	3.52	1.68	47.7	7	6	Total	58.95	23.40	39.7	78	85
April	2.07	.44	21.2	2	2	1915.					
May	3.40	.20	5.9	1	3	January	5.38	3.61	67.0	12	5
June	2.15	.00	.0	0	6	February	5.72	3.29	57.5	12	5
July	9.09	1.23	13.5	5	13	March	1.90	2.48	130.5	9	5
August	4.45	.77	17.3	3	5	April	.02	.00	.0	0	1
September	9.09	2.42	26.6	9	15	May	2.68	.00	.0	0	7
October	4.20	4.02	96.0	17	5	June	2.78	.22	7.9	1	8
November	3.14	.96	30.6	3	5	July	5.25	.15	21.9	4	9
December	2.20	1.72	78.2	9	7	August	6.99	.86	12.3	3	12
Total	63.60	27.27	42.8	112	90	September	2.35	.00	.0	0	9
1914.						October[a]					
January	1.23	1.28	104.1	5	1	November	1.55	1.34	86.5	6	3
February	5.69	1.72	30.2	6	5	December	2.12	.63	29.7	3	6
March	3.86	3.04	78.8	10	5	Total	36.74	13.58	37.0	50	70
April	6.34	3.65	57.6	8	4	Averages for period (3.0 years)	53.0	21.4	40.4	80	81.7
May	2.33	.64	27.5	3	7						
June	4.12	.41	10.0	2	5						
July	7.28	1.32	18.1	6	15						
August	7.07	1.51	21.4	6	17						

[a] Record omitted.

ACTUAL RATES OF RUN-OFF DUE TO HEAVY STORMS

In the foregoing tables of rainfall and run-off the figures under the columns headed "Run-off," with the exception of those shown for the New Orleans Land Company tract, are in fact the amounts pumped rather than the run-off of the water from the surface into the main drainage channels. In the case of the tract excepted, the water discharges by gravity as fast as it enters the main outfall channel. For almost the entire period covered by the record of each plant, an hourly reading has been made of the stage of water in the main reservoir canal during the operation of the pumping plant. The amounts of water stored in the main drainage channels at the different levels have also been calculated. By this means the amounts pumped per day during the heavy storms have been so adjusted for a number of typical storms on each district that the final results represent approximately the quantity of water which would have been removed had the pumps taken the water as fast as it entered the main reservoir channels; in other words, these results represent approximately the true run-off for the storms selected. With the exception of a very few heavy storms, only those were selected which occurred when the land in the district was saturated, or at least fairly wet.

Table XI gives the dates, rainfall, and revised run-off for these selected storms. In the columns headed "Rainfall" are indicated by the words "Moist," "Dry," etc., the condition of the land at the beginning of the storm periods. While the run-off is given as for consecutive dates after the beginning of pumping, this is not strictly correct, as the run-off was computed for 24-hour periods following the starting of the pumps, regardless of the calendar dates. Following each table are shown the number of heavy storms occurring when the land was dry and the number occurring when the land was wet. These figures include all of the 2- and 4-inch storms that occurred during the entire period of observation.

TABLE XI.—*Typical heavy storms and probable actual run-off of all districts*

SMITHPORT PLANTING COMPANY TRACT [a]

Date.	Rainfall.	Run-off.	Date.	Rainfall.	Run-off.
1909.	*Inches.*	*Inches.*	1913.	*Inches.*	*Inches.*
Aug. 10	1.68	0.89	Sept. 12	0.80	.....
11	2.80	1.15	13	3.00	1.27
12	Moist.	.48	14	.15	1.18
13	.....	.11	15	Wet.	.03
1911.			26	.42	.....
Apr. 25	1.02	.....	27	2.80	1.20
26	2.02	.97	28	Wet.	.63
27	Dry.	.50	29	.....	.13
28	.....	.02	1914.		
Nov. 27	3.00	1.02	Feb. 27	2.00	.....
28	Moist.	.48	28	Wet.	1.10
29	.....	.03	Mar. 1	.....	.74

[a] From June, 1909, to December, 1915, of all of the storms of over 2 inches, 8 occurred on dry land and 21 on wet land; of those of over 4 inches, 3 occurred on dry land and 1 on wet land.

TABLE XI.—*Typical heavy storms and probable actual run-off of all districts*—Contd.

SMITHPORT PLANTING COMPANY TRACT—continued

Date.	Rainfall.	Run-off.	Date.	Rainfall.	Run-off.
1914.	*Inches.*	*Inches.*	1915.	*Inches.*	*Inches.*
Mar. 2	.....	0.01	Jan. 23	2.30	1.22
Oct. 2	2.10	.00	24	Wet.	.47
3	Saturated	1.37	25	.....	.....
4	.....	.68	Mar. 2	.37	[a].00
Nov. 12	.47	.....	3	1.09	1.02
13	2.40	.96	4	.51	.47
14	Wet.	.53	July 2	1.00	.....
15	.....	.20	3	2.00	1.18
16	.....	.26	4	1.50	1.04
26	2.70	.....	5	.....	.84
27	3.00	1.62	6	.....	.15
28	.....	1.20			
29	.....	1.06			
30	.....	.86			

WILLSWOOD PLANTATION [b]

1909.			1912.		
June 2	4.10	1.29	Apr. 14	3.93	.99
3	1.00	1.36	15	Wet.	1.29
4	Dry.	.44	May 10	4.50	1.26
5	.....	.18	11	Wet.	1.27
Sept. 20	4.14	1.23	12	.....	1.03
21	.30	.64	Dec. 5	1.60	.81
22	Wet.	.25	6	2.73	.39
Dec. 11	3.12	.....	7	Wet.	1.43
12	.27	1.00	8	.....	1.18
13	Wet.	.37	9	.....	.06
14	.....	.27			
15	.....	.36	1913.		
			Apr. 24	3.09	.....
1911.			25	Moist.	1.08
Apr. 8	3.55	.....	26	.....	.77
9	Wet.	[a] 1.29	Sept. 13	2.75	1.02
10	.30	.54	14	Wet.	1.19
11	.....	.42	15	.....	.54
12	.....	.40			
25	4.05	[a] 1.07	1915.		
26	2.21	1.15	Jan. 23	2.97	1.40
27	Wet.	1.15	24	Wet.	.79
28	.....	.64	Oct. 3	1.38	.....
			4	1.90	.90
1912.			5	1.46	1.55
Jan. 7	2.18	.....	6	Saturated.	1.55
8	.60	1.27			
9	.00	.82	7	.....	1.53
10	Wet.	.25	8	.....	1.00
11	.....	.42	12	3.11	1.05
Mar. 22	1.85	.20	13	2.48	1.44
23	2.02	.98	14	Saturated.	1.44
24	.....	.72			
25	.....	.40	15	.....	1.44
Apr. 13	1.42	.73	16	.....	.16

[a] Not corrected for storage in canal.

[b] From June, 1909, to December, 1915, of all of the storms of over 2 inches, 14 occurred on dry land and 25 on wet land; of those of over 4 inches, 2 occurred on dry land and 4 on wet land.

TABLE XI.—*Typical heavy storms and probable actual run-off of all districts*—Contd.

LAFOURCHE DRAINAGE DISTRICT NO. 12, SUBDISTRICT NO. 1[a]

Date.	Rainfall.	Run-off.	Date.	Rainfall.	Run-off.
1914.	*Inches.*	*Inches.*	1915.	*Inches.*	*Inches.*
Nov. 13	6.50	0.00	Jan. 23	2.70	1.75
14	Dry.	2.06	24	Wet.	.46
15	.....	.69	25	.....	.36
27	4.20	2.06	Feb. 4	2.30	[b].00
28	Moist.	1.11	5	Wet.	.96
29	.....	.65	6	.....	.49
30	.....	.29	July 3	3.50	([b])
Dec. 1	.....	.29	4	Dry.	1.23
			5	.....	.87

NEW ORLEANS LAND COMPANY TRACT[c]

1909.			1912.		
Dec. 12	2.74	.34	Apr. 19	.....	.31
13	Wet.	.33	Dec. 5	1.00	.....
14	.80	.32	6	3.00	1.36
15	.....	.31	7	Wet.	.45
1911.			8	.....	.32
Mar. 22	3.80	.76	9	.....	.26
23	Moist.	.41			
24	.....	.36	1913.		
25	1.15	.30	May 22	2.95	.62
26	.....	.00	23	1.63	.51
Apr. 8	4.03	1.19	24	Wet.	.30
9	Saturated	.51	25	.....	.22
10	.....	.27	Aug. 17	2.60	.38
11	.....	.00	Aug. 18	Wet.	.27
26	3.80	.95	19	.....	.22
27	Saturated	.76	Sept. 14	4.32	1.51
28	.....	.58	15	Water on surface.	.85
1912.			16		.64
Jan. 8	2.41	.64	17	.....	.50
9	Saturated	.46	18	.....	.38
10	.....	.33			
11	.....	.26	1914.		
Mar. 12	2.30	.42	Apr. 19	3.14	.79
13	Wet.	.30	20	Dry.	.36
14	.....	.23	21	.....	.24
15	.....	.20	Aug. 26	1.40	.00
22	3.60	.....	27	1.88	.48
23	2.40	1.09	28	1.59	.39
24	Saturated	1.78	29	Dry.	.29
25	.....	.84	30	.....	.28
26	.....	.42	Sept. 24	3.30	.78
27	.....	.31	25	Saturated	.60
Apr. 15	2.10	1.42	26	.....	.37
16	1.60	1.08	Dec. 29	2.00	.34
17	Water on surface.	.69	30	Moist.	.22
18		.44	31	.....	.16

[a] From November, 1913, to December, 1915, of all of the storms of over 2 inches, 4 occurred on dry land and 8 on wet land; of those of over 4 inches, 3 occurred on dry land and 3 on wet land.

[b] Not corrected for storage in canal.

[c] From June, 1909, to December, 1915, of all the storms of over 2 inches, 12 occurred on dry land and 24 on wet land; of those of over 4 inches, 1 occurred on dry land and 3 on wet land.

TABLE XI.—*Typical heavy storms and probable actual run-off of all districts*—Contd

NEW ORLEANS LAND COMPANY TRACT—continued.

Date.	Rainfall.	Run-off.	Date.	Rainfall.	Run-off.
1915.	*Inches.*	*Inches.*	1915.	*Inches.*	*Inches.*
Jan. 17	1.90	0.31	July 6	Wet.	0.28
18	Wet.	.26	Aug. 11	2.00	.26
19		.20	12	Moist.	.17
23	3.25		13		.11
24	Saturated	.84	14		.10
25		.49	Oct. 13	4.90	2.10
26		.33	14	Water on surface.	.84
27		.24	15		.55
Feb. 5	1.36	.51	16		.40
6	Saturated	.31	17		.33
7		.24			
8		.18			
July 3	1.80	.38			
4	1.73 4.38	.43			
5	.85	.40			

UNIT NO. 1, POYDRAS, LA.[a]

1913.			1915.		
Sept. 30	2.13	1.12	Jan. 16	1.32	.08
Oct. 1	1.10	1.00	17	1.03	.79
2	Wet.	.39	18	Wet.	.35
1914.			19		.27
Feb. 27	2.30		20		.12
28	.26	1.39	23	2.52	1.69
Mar. 1	Wet.	.71	24	Wet.	.25
25	1.97		June 13	5.30	[b] .74
26	.00		14	.30	.17
27	2.75		15	Dry.	.04
28	Wet.	[b] 1.31	July 3	3.03	.80
29		.00	4	Moist.	.49
30		.26	5	.31	.26
			6		.08

GUEYDON DRAINAGE DISTRICT, SUBDISTRICT NO. 1[c]

1912.			1913.	*Inches.*	*Inches.*
June 5	3.03	.82	June 17	Dry.	.85
6	.50	.87	18		.19
7	Wet.	.61	July 23	5.00	1.52
Dec. 21	3.25	1.27	24	Wet.	.67
22	2.60	1.28	25	.10	.32
23	Wet.	.69	Sept. 13	2.20	1.08
24		.22	14	Wet.	.52
1913.			15		.11
Jan. 26	3.20	1.07	26	5.70	1.65
27	Wet.	.47	27	.60	1.07
28		.23	28	1.60	1.04
June 15	4.30		29	.30	.66
16	1.10	.94	30	3.20	.55
			Oct. 1	.40	.67

[a] From March, 1912, to Dec., 1915, of all of the storms of over 2 inches, 8 occurred on dry land and 17 on wet land; of those of over 4 inches, 2 occurred on dry land and 4 on wet land.

[b] Not corrected for storage in canal.

[c] From March, 1912, to December, 1915, of all of the storms of over 2 inches, 11 occurred on dry land and 13 on wet land; of those of over 4 inches, 4 occurred on dry land and 3 on wet land.

TABLE XI.—*Typical heavy storms and probable actual run-off of all districts*—Contd.

GUEYDON DRAINAGE DISTRICT, SUBDISTRICT NO. 1—continued

Date.	Rainfall.	Run-off.	Date.	Rainfall.	Run-off.
1909.	*Inches.*	*Inches.*	1914.	*Inches.*	*Inches.*
Oct. 2	Wet.	0.96	Apr. 23	.....	0.39
3	.....	.92	24	.....	.02
4	.....	.84	28	1.00	.99
5	.....	.57	29	1.35	.53
22	5.10	0.96	30	Moist.	.77
23	Wet.	1.30	May 1	.....	.52
24	.....	.90	Nov. 13	.75	1.04
25	.....	.27	14	2.95	.80
1914.			15	Moist.	.13
Feb. 12	3.50	.00	26	.45	1.45
13	Moist.	.99	27	2.10	.55
14	.....	.47	28	Wet.	.31
Apr. 18	5.77	1.77	1915.		
19	Dry.	.82	July 4	3.85	[a] 1.19
20	.....	.60	5	.12	1.44
21	.....	.69	6	Wet.	.41
22	.....	.94	7	.....	.16

LITTLE WOODS TRACT [b]

	1915.				1915.	
Jan.	23	2.70	1.06	July 6	1.30	.58
	24	Wet.	.60	7	Dry.	.39
	25	.....	.02	8	.....	.05
July	2	1.00	.....	Dec. 16	1.30	.61
	3	3.10	.60	17	1.80	.66
	4	1.40	.41	18	Wet.	.08
	5	.10	.19	19	.....	.18

DES ALLEMANDS POLDER NO. 1 [c]

	1913.				1914.	
July	24	2.00	.63	Apr. 18	4.00	1.09
	25	Moist.	.28	19	Dry.	.80
Sept.	30	3.30	1.01	20	.....	.43
Oct.	1	Moist.	.83	21	.....	.16
	2	.....	.70	Nov. 27	5.45	.95
	3	.....	.42	28	Dry.	.65
	4	.....	.28	29	.....	.66
	5	.....	.11	30	.....	.51
	1914.			Dec. 1	.....	.35
Feb.	28	2.20	.96	2	.....	.05
Mar.	1	Wet.	.37	1915.		
	2	.....	.12	Jan. 23	3.00	1.04
				24	Wet.	.63
				25	.....	.43
				26	.....	.19

[a] Not corrected for storage in canal.
[b] From October, 1908, to December, 1915, of all the storms of over 2 inches, 11 occurred on dry land and 21 on wet land; of those of over 4 inches, 2 occurred on dry land and 4 on wet land.
[c] From December, 1912, to December, 1915, of all the storms of over 2 inches, 10 occurred on dry land and 12 on wet land; of those of over 4 inches, 2 occurred on dry land and 2 on wet land.

TABLE XI.—*Typical heavy storms and probable actual run-off of all districts*—Contd.

JEFFERSON DRAINAGE DISTRICT NO. 3, FEBRUARY, 1913–DECEMBER, 1915[a]

Date.	Rainfall.	Run-off.	Date.	Rainfall.	Run-off.
1913.	*Inches.*	*Inches.*	1914.	*Inches.*	*Inches.*
Apr. 24	2.76	0.34	Feb. 15	.....	0.17
25	.47	.42	28	3.19	1.02
26	Moist.	.41	Mar. 1	Wet.	.63
May 22	3.00	.64	2	.....	.51
23	Dry.	.39	25	4.70	1.12
Sept. 13	2.00	.71	26	Dry.	.49
14	4.05	.70	27	1.30	1.10
15	Wet.	1.15	28	.....	.20
16	.....	1.02	29	.....	.05
17	.....	.77	Apr. 19	4.32	1.17
18	.....	.39	20	Dry.	.01
19	.....	.00	1915.		
1914.			Oct. 13	5.00	1.73
Feb. 13	3.19	.87	14	Saturated.	.85
14	Moist.	.49			

LAFOURCHE DRAINAGE DISTRICT NO. 12, SUBDISTRICT NO. 3[b]

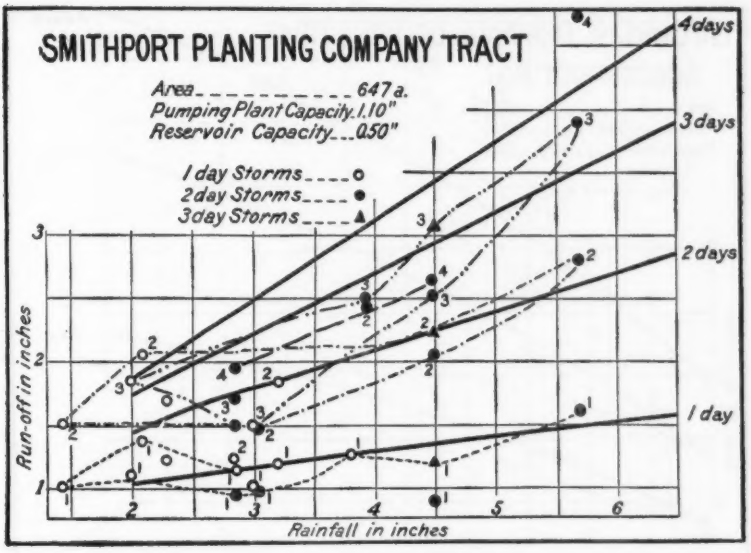
1914.			1914.		
Apr. 18	4.68	.....	Nov. 28	.....	.94
19	Dry.	1.35	29	.....	.41
20	.....	.62	30	.....	.25
21	.....	.10	1915.		
Nov. 13	5.25	.00	Jan. 23	2.55	1.05
14	Moist-dry.	1.30	24	Wet.	.20
15	.....	.34	25	.....	.00
16	.....	.19	Feb. 4	1.88	.....
26	4.57	.....	5	Wet.	.67
27	Wet.	1.62	6	.....	.12

[a] From February, 1913, to December, 1914, of all of the storms of over 2 inches, 5 occurred on dry land and 9 on wet land; of those of over 4 inches, 3 occurred on dry land and 2 on wet land.

[b] From December, 1912, to December, 1915, of all of the storms of over 2 inches, 6 occurred on dry land and 11 on wet land; of those of over 4 inches, 3 occurred on dry land and 3 on wet land.

CONCLUSIONS

Owing to differences in the degree of wetness of the land, the intensity of the rainfall, the time of the year, the condition of the drainage channels, etc., the results for any particular district are not uniform. However, to make it possible to judge what run-off would occur under average conditions the results in the tables have been shown in curves (fig. 1–4). The amounts of the run-off (in inches of depth) for one, two, three, and four day periods have been plotted as ordinates and the rainfall (in inches for each storm) as abscissas. Distinctive lines have been drawn through the points representing the run-off for each length of storm period. Each curve has been drawn, so far as practicable, to average these points and at the same time to conform to the other curves. With



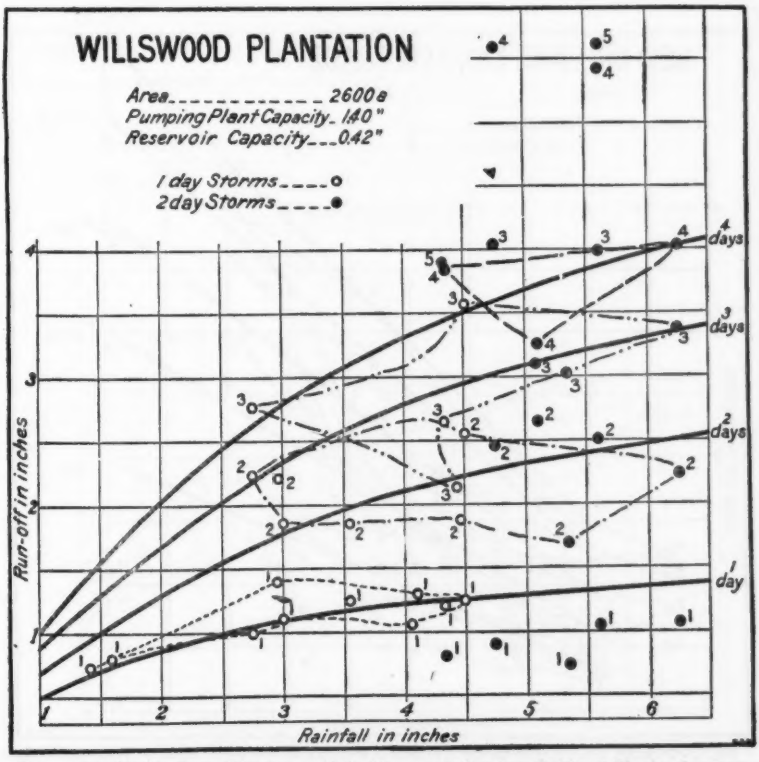


FIG. 1.—Probable actual run-off for storm periods of from one to four days, Smithport Planting Company tract and Willswood Plantation.

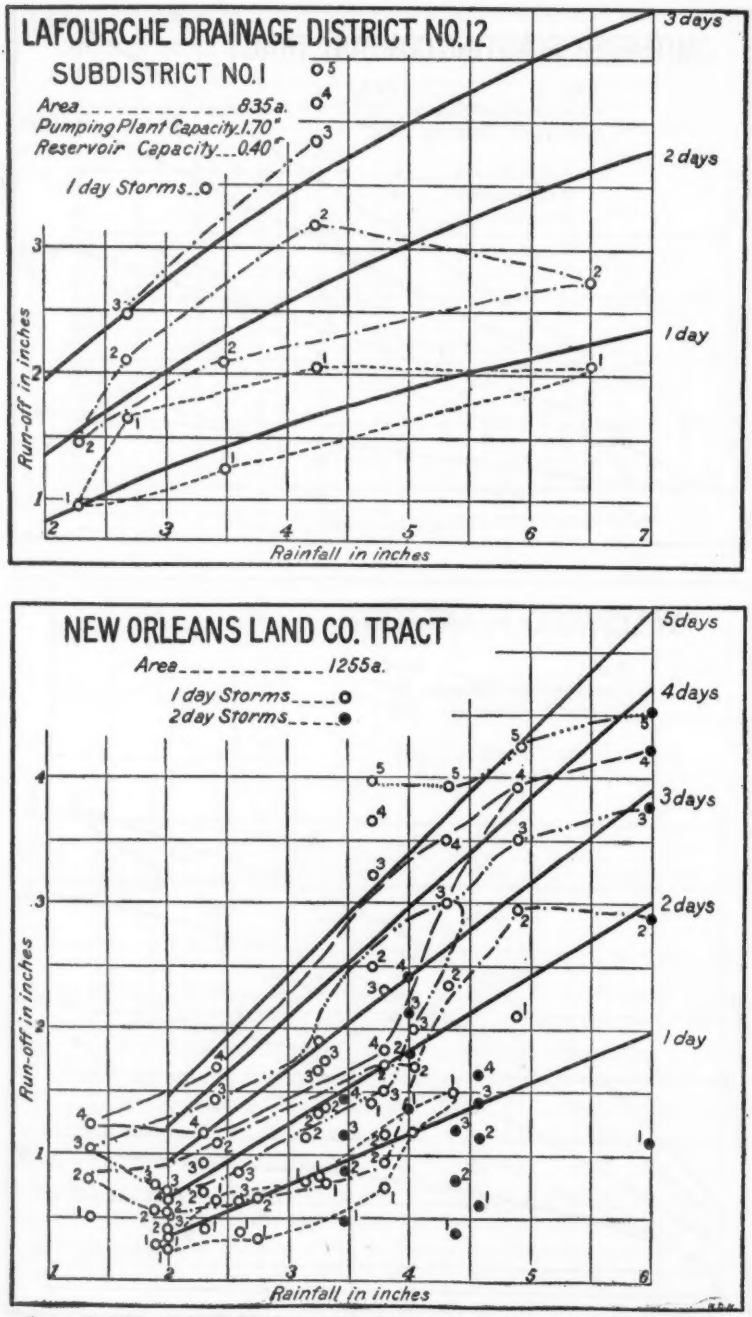
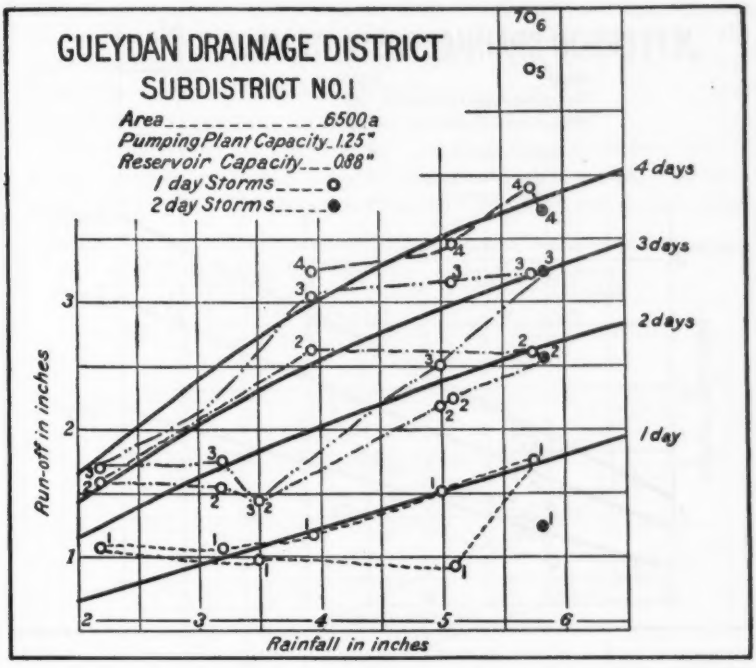


FIG. 2.—Probable actual run-off for storm periods of from one to five days, Lafourche Drainage District No. 12 and New Orleans Land Company tract.



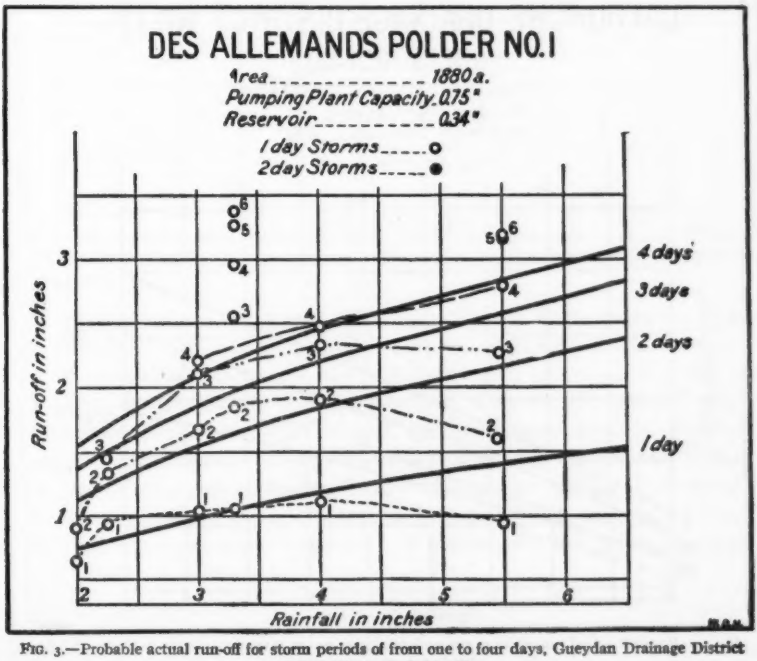
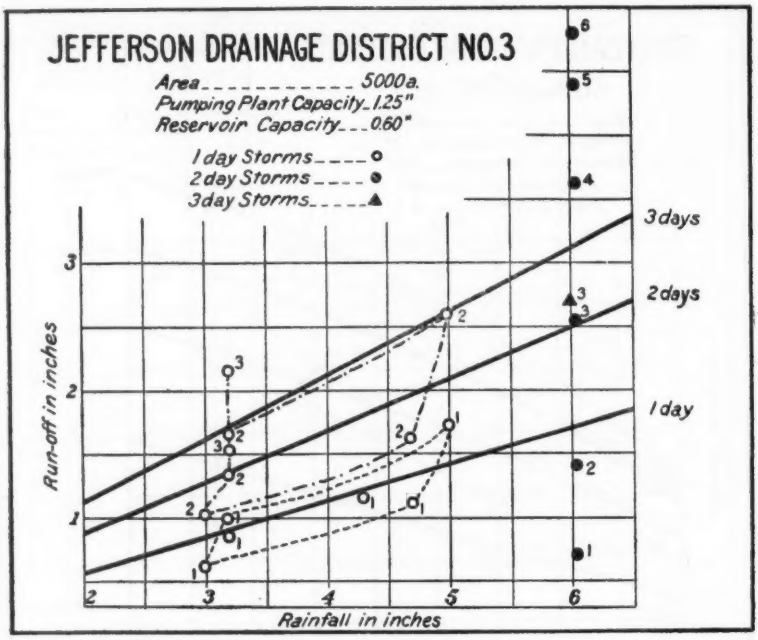


FIG. 3.—Probable actual run-off for storm periods of from one to four days, Gueydan Drainage District and Des Allemands Polder No. 1.



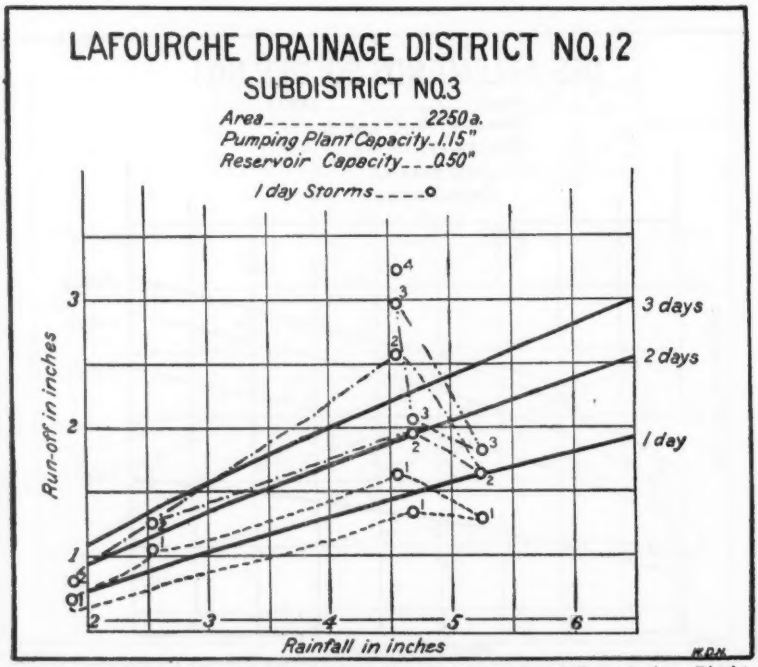


FIG. 4.—Probable actual run-off for storm periods of from one to three days, Jefferson Drainage District No. 3 and Lafourche Drainage District No. 12.

each set of curves is shown the area of the district, the average capacity of the pumping plant per 24 hours, and the storage capacity of the main drainage channels between the surface and a level 5 feet below. From these separate curves composite curves have been drawn which represent the average run-off from all the districts (fig. 5).

It is evident that the effect on the run-off of a change in the capacity of the pumping plant can not all be measured by the change of level of the water in the main reservoir channels, as greater slope and velocity

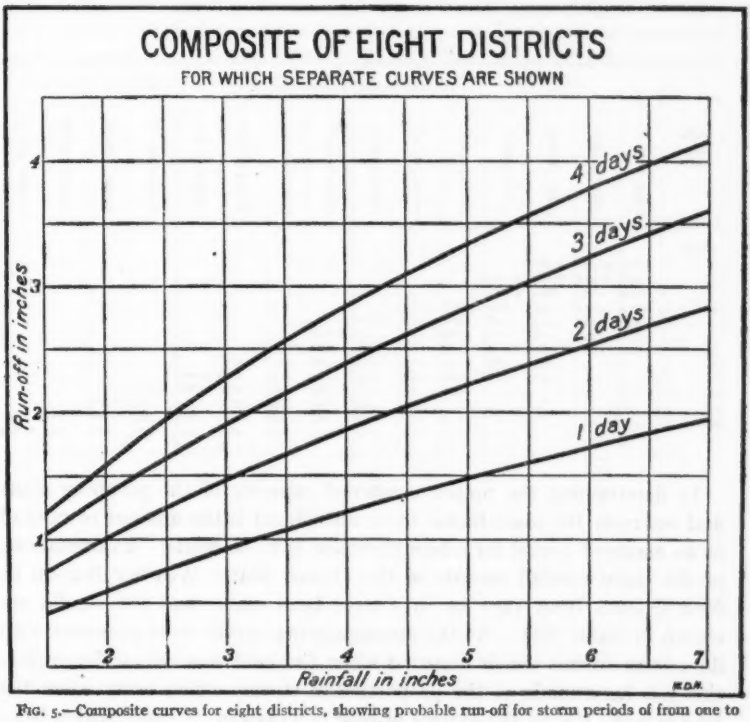


FIG. 5.—Composite curves for eight districts, showing probable run-off for storm periods of from one to four days.

of water occur in the drainage channels when a larger pumping plant is installed. This effect extends even to the small field ditches.

In estimating the run-off likely to result from an assumed storm on a given district the curve used should be that for the district which resembles the given district in area, pumping-plant capacity, reservoir capacity, and general conditions. The curves may be considered only as representing general tendencies and not definite values. They should be of service, however, in making the proper adjustment between reservoir and pumping-plant capacity. A method for making this adjust-

ment has been outlined by Okey.[1] It is believed that, in general, after a capacity of about 0.50 inch of water over the area drained has been provided in the main reservoir channels between the surface and a level 5 feet below it will be cheaper to obtain increased capacity to handle storms by enlarging the pumping plant rather than the reservoir. This will depend, however, on local costs for excavation and pumping machinery.

TABLE XII.—*Average yearly number of storms of given intensities, based on daily rainfall records of the United States Weather Bureau for New Orleans, La., 1871 to 1915, inclusive*

Total rainfall.	Average number of storms per year.														
	1-day period.	2-day period.	3-day period.	4-day period.	5-day period.	6-day period.	7-day period.	8-day period.	9-day period.	10-day period.	11-day period.	12-day period.	13-day period.	14-day period.	15-day period.
Inches.															
3	1.622	3.020	4.060	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	0.688	1.358	1.869	2.220	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	.333	.644	.866	1.043	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	.200	.333	.466	.644	.778	0.866	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	.156	.222	.311	.356	.400	.489	0.600	.....	.....	.....	.....	.....	.....	.....	.....
8	.111	.156	.156	.222	.289	.289	.333	0.378	.....	.....	.....	.....	.....	.....	.....
9	.022	.066	.089	.111	.156	.200	.200	.245	0.311	.....	.....	.....	.....	.....	.....
10	.....	.....	.044	.066	.111	.156	.200	.200	.245	0.267	.....	.....	.....	.....	.....
11	.....	.....	.022	.044	.066	.066	.089	.133	.133	.178	0.200	.....	.....	.....	.....
12	.....	.....	.....	.....	.044	.066	.089	.089	.089	.089	.089	0.111	.....	.....	.....
13	.....	.....	.....	.....	.....	.022	.044	.044	.044	.044	.044	.444	0.089	.....	.....
14	.....	.....	.....	.....	.....	.022	.022	.022	.022	.022	.022	.022	.066	0.066	.....
15	.....	.....	.....	.....	.....	.022	.022	.022	.022	.022	.022	.022	.014	.044	0.044

In determining the proper combined capacity of the pumping plant and reservoir the main factor to be considered is the amount of rainfall in an assumed period for which provision is to be made. Examinations of the daily rainfall records of the United States Weather Bureau at New Orleans from 1871 to 1915 have been made, and the results are shown in Table XII. As the accompanying curves were prepared with data from storms which occurred when the land was wet, a determination has been made of the proportion of storms which occur when the land is wet. Of all the storms of over 2 inches in 24 hours which have occurred on the districts during the time covered by the records, 64 per cent occurred on a wet and 36 per cent on a dry surface; of all storms over 4 inches the percentages are 54 per cent and 46 per cent, respectively. Of course the storage capacity of the land influences the run-off from the small storms relatively much more than it does that from the large ones. However, an examination of the daily rainfall and pumping records will show that heavy rains on a dry soil do not make very heavy demand on the pumping plant. It is believed, therefore, that a reduc-

[1] OKEY, C. W. THE WET LANDS OF SOUTHERN LOUISIANA AND THEIR DRAINAGE. U. S. Dept. Agr. Bul. 71, p. 71–75. 1914.

tion of about 30 per cent in the average frequency of storms could be made safely and that the resulting figure would be the proper one for use. If the character of operations that are to be conducted on the land of a given district is known, a decision can then be made as to the heaviest storm for which provision must be made. On a district where staple crops are to be raised it would be economical to allow a certain amount of flooding oftener than would be advisable on land where high-priced truck crops are to be raised, while in residence districts it would be very desirable to prevent all surface flooding. In addition to the damage to crops due to flooding, there are other factors to be considered, such as inconvenience to residents and the possible depressing influence on land values of floodings occurring even at infrequent intervals.

DIAGNOSING WHITE-PINE BLISTER-RUST FROM ITS MYCELIUM

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INTRODUCTION

The mycelium of *Cronartium ribicola* Fischer, the causal organism of the white-pine blister-rust, can be found among the cells of *Pinus strobus* L. for some time before the spores of the fungus are produced. The examination of thousands of sections of diseased bark has convinced the writer that the morphological characters of the mycelium and its method of parasitism are sufficiently distinctive to warrant the assertion that the blister-rust can be recognized from the mycelium alone.

The stains generally employed in the preparation of slides for diagnosis are safranin and lichtgruen. The use of these two stains is, of course, already well established in both zoological and botanical work, and their employment in combination is by no means new. They are particularly valuable in the study of the blister-rust mycelium because they not only stain host and parasite at the same time but they also bring out extremely well the anatomical features of the host tissue. It has always seemed to the writer that more detailed accounts of the experiences of investigators in handling stains would be of very great value to students. Accordingly the method which has been employed is given below, step by step, with the hope that it may be useful and suggestive to investigators of both normal and pathological anatomy. Throughout, the writer has kept in mind the fact that there has been very little published in this country on the use of the stains in combination.

METHOD OF DOUBLE STAINING

(*a*) SECTIONS.—Free-hand sections of white-pine bark can be made to answer very well if no microtome is available, but many more sections of a better quality can be obtained with an ether or carbon-dioxid freezing attachment and a small microtome. Radial longitudinal sections are best, for in them the medullary rays are exposed, and in infected bark the mycelium of the blister-rust is generally closely associated with the cells of the rays. The sections should include, where practicable, the whole width of the bark, the cambium region, and three or four annual rings of wood. Such sections are, of course, larger than can be conveniently cut with a section razor by hand, but it is perfectly possible to

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cut them with the freezing microtome if the operator is careful not to cut them too thin. The advantage in having sections of such large size lies in the fact that the observer can explore the whole of the susceptible regions for evidence of the mycelium of the parasite under conditions really favorable for its discovery.

No killing solution is used, but, so far as can be observed, no shrinkage at all occurs in the hyphæ, and but little in the host cells of fresh specimens. The blocks of bark and wood should be cut into pieces approximately ⅛ to ¼ inch on a side. The prepared blocks are then soaked for about 10 minutes in a 10 per cent aqueous solution of gum arabic containing 0.5 per cent of phenol. Blocks cut from fresh specimens can be put to soak at once. If the specimen is old and dry, the blocks should be boiled before being put into the gum arabic. The same strength gum-arabic solution is used as a freezing medium. If the material be embedded in paraffin, the usual process of sectioning and mounting can be followed. Excellent sections of young pine bark extending from cambium to epidermis can be easily cut 5 μ thick from paraffin material. However, for ordinary diagnosis or morphological study of the fungus hyphæ sections 15 to 20 μ thick, cut on the freezing microtome, are very satisfactory. Such sections should be removed from the knife with a moist camel's-hair brush and rinsed in several changes of clean water. They can be handled very conveniently in bevel-ground Syracuse watch glasses.

(*b*) STAINS.—The stains, safranin and lichtgruen, should be kept in dropper bottles of 25-to-50-c. c. capacity and used from the dropper or pipette. Similar bottles should be used for absolute alcohol, clove oil, and xylol. The writer uses the alcoholic solution of safranin almost exclusively. This method is described by Chamberlain [1] as follows:

> The alcoholic solution is made by dissolving 1 g. of the alcoholic safranin in 100 c. c. of 95 per cent or absolute alcohol, and, after the safranin is completely dissolved, adding 50 c. c. of distilled water.

This stain may be used over and over again, but it should preferably be filtered back into the drop bottle after each staining. A convenient stock solution of lichtgruen is a 1 per cent in 95 per cent alcohol. A convenient strength for use is one-half stock, made by diluting the stock with an equal volume of 95 per cent alcohol. For thin sections, however, from paraffin material, better results can be obtained by the rapid use of the stain at full strength. In addition to the regular drop bottle pipettes, there should be two or three others of good capacity and small tube opening for use in draining off the stains or excess reagents during the steps of the process.

(*c*) STAINING PROCESS.—The sections should be rinsed several times and then drained of all excess water and a generous quantity of safranin added. This stain should remain for from two to four hours, after

[1] CHAMBERLAIN, C. J. METHODS IN PLANT HISTOLOGY. ed. 3, p. 51. Chicago, 1915.

which time it may be drawn off and kept to be filtered back into the drop bottle. By tilting the watch glass the sections can be grouped easily at one side of the watch glass. Then, after the safranin has been drawn off, any excess red in the dish may be wiped out with a cloth. Care should be taken that the sections do not dry out. The lichtgruen should be added as soon as the excess safranin is removed. A muddy mixture of red and green results. The lichtgruen replaces the safranin quite rapidly, so that a minute is usually the maximum time necessary to produce the proper green tint. The writer shakes the watch glass as soon as the lightgruen is added, then draws off the red-green mixture, and adds a few drops of fresh lichtgruen. The green stain should not be allowed to act long enough to wash out too much of the safranin. The time required depends on (1) the thickness of the sections, (2) the time the sections were stained in safranin, and (3) the strength of the lichtgruen solution. The used lichtgruen should be thrown into a waste jar.

(*d*) CLEARING AND MOUNTING.—After the removal of the green stain, absolute alcohol should be added immediately and the watch glass rocked or shaken. This absolute alcohol should be drawn off and saved in a waste jar, and the sections treated with fresh absolute alcohol for a minute or two, the total time depending on the number of sections handled at one time. This absolute alcohol should then be replaced by clove oil. While in clove oil the sections may be conveniently lifted with a small brush and arranged on the slide without danger of drying up, and for this reason clove oil is used between absolute alcohol and the more volatile xylol. After the sections are arranged, they should be rinsed with drops of xylol until the clove oil has been removed. A drop of balsam and a warm cover complete the mount. It is advisable to set the slide away for a day in the paraffin bath with a heavy lead weight on the cover to flatten out the sections.

(*e*) COLOR RESULTS.—The color results in the finished slide vary slightly, depending on the amount of safranin which was removed when the green stain was acting. A good diagnostic slide for *Cronartium ribicola* should have red host nucleoli and reddish nuclei, red wood cells, dead cells, and cork cells. Occasionally resin cells stain a deep red. The host cytoplasm and all cellulose walls should be green. The hyphæ of the parasite stain green, but they stand out well when they are colored a greenish pink or greenish red—that is, when the red is not removed too far. The nuclei of the parasite should be red. Although the stains employed do not result in the differential staining of the host and parasite, there is no difficulty in distinguishing them.

(*f*) ADVANTAGES OF THE METHOD.—The chief advantages of the method are its simplicity and rapidity. Permanent record slides from a suspected specimen can be completed easily in about two and one-half hours from the time the specimens reach the laboratory. Correctly

prepared slides are sufficiently transparent for a thorough exploration with oil-immersion lenses. The practicability of the method has been demonstrated by constant use during the past year in the diagnosis of suspected cases of blister-rust and in the study of the anatomical features of parasite and host.

MYCELIUM OF THE PARASITE

The characters which distinguish the hyphæ of *Cronartium ribicola* from other hyphæ occasionally found in white-pine bark are their comparatively large size, fairly uniform diameter, and possession of haustoria. They are larger than any other parasitic hyphæ which the writer has observed in pine bark. While there is, of course, some difference in the width of individual hyphæ one rarely finds them deviating widely from the average width of 3 to 3.5 μ. The haustoria are particularly striking. They invade practically every cell in the infected region in young bark. In older bark they are most prominent in the cells of the medullary rays; and for this reason, as mentioned above, radial sections are particularly satisfactory for study. At the point where the haustoria pass through the cell wall, they are constricted. Once inside the cell their width increases until they average a little more than 4 μ in diameter (Pl. 31, B). Prominent bulges, which occur quite frequently, give them a characteristically irregular outline. When young and short they are straight; as they mature they usually develop pronounced bends, which may be as great as right angles. The host nuclei appear to attract the haustoria. Frequently their tips press dents in the sides of the host nuclei (fig. 1, a), recalling the occurrence of this well-known phenomenon in many other rusts; but, so far as the writer has been able to observe, the nucleus does not appear to suffer greatly from this close association with the parasite. In fact, the cells in which the haustoria are present seem to be quite as healthy as the cells which have remained free from attack. Usually the haustoria are unbranched; but in some instances, especially in the cells of the medullary rays, they branch (fig. 1, b). In no case have more than three tips been observed. All the cells of the mycelium, including the haustoria, are uninucleate until cell fusion occurs at the base of the æcium.

The Peronosporales and the Erysiphaceae are the only other groups of parasitic fungi beside the Uredinales which possess prominent haustoria. No members of the first two groups are known to parasitize the bark of *Pinus strobus*. Moreover, the second group is composed of leaf parasites whose mycelium is almost entirely exterior. Even if by any chance material containing mycelium from either of these two groups should be introduced into the mount along with the bark sections, there would be no danger of confusion. The fact that the members of the first group have cœnocytic hyphæ and that the members of the second group possess

haustoria which are decidedly different in appearance [1] from those of the blister-rust, rules out any possibility of confusing the mycelium of members of either of the two groups with the mycelium which has been described.

METHOD OF PARASITISM

The manner in which the parasite attacks the host is also important as a distinguishing character. The hyphæ are intercellular in position. As stated above, practically every cell of the bark may be pierced by one or more haustoria. Parenchyma cells of the cortex and in the neighborhood of the resin ducts, sieve cells, medullary-ray cells, and even resin cells are all subject to attack. Only the cork and schlerenchyma

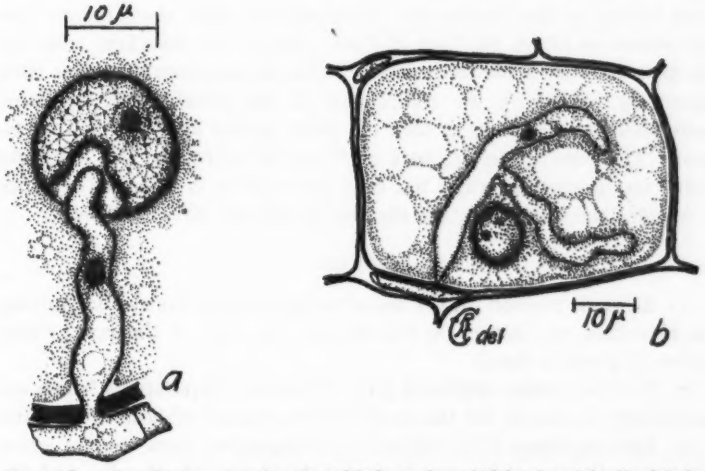


FIG. 1.—*Cronartium ribicola: a*, A moderately straight haustorium which has dented the side of the host nucleus. Note the manner in which the haustorium is constricted in passing through the cell wall. *b*, A branched haustorium in a young medullary-ray cell. The figures were drawn with the aid of a camera lucida.

cells of old bark and, of course, dead bark are apparently immune. The hyphæ may follow the medullary rays past the cambium and into the xylem for at least three annual rings, and in these medullary-ray cells the haustoria are quite as prominent as in the ray cells of the phloem. Haustoria do not enter the wood cells. The parenchyma cells surrounding the resin ducts in the last two annual rings of xylem are also heavily attacked. In tangential or radial sections one sees that the hyphæ are frequently massed in strands (Pl. 31, A). These strands are often formed in the region of the thin-walled sieve tubes, but they are also scattered through the parenchyma. Generally the medullary-ray cells are forced apart by single layers of hyphæ. Probably the swelling of the bark is

[1] SMITH, Grant. THE HAUSTORIA OF THE ERYSIPHEÆ. *In* Bot. Gaz., v. 29, no. 3, p. 153-184, pl. 11-12. 1900.

due almost entirely to the spreading action of the hyphæ as they force themselves between the cells. This method of attack differs from that of other parasitic fungi observed on white-pine bark. In attacks made by species of Phoma and Fusicoccum the cells are killed, the hyphæ run through the cells, and the bark tends to dry up, turn brown, and crack; whereas in the case of the blister-rust attack the cells remain alive for a long time, the hyphæ run between the cells, the bark swells, turns a yellowish green color, and does not crack until the æcia are produced.

VALUE OF MYCELIAL CHARACTERS, HAUSTORIA, AND METHOD OF PARASITISM IN DIAGNOSIS

It is evident from the above discussion that the mycelium described must belong to the Uredinales. Furthermore, since there is only one rust known to attack the bark of *Pinus strobus*, the mycelium must be the mycelium of *Cronartium ribicola*. This obvious conclusion has been vigorously proved by the comparison of the mycelium in suspected cases with the mycelium in bark on which pycnia and æcia had developed. The presence in the bark of *P. strobus* of hyphæ and haustoria fitting the description which has been given above is sufficient evidence to warrant the conclusion that the pine is infected with *C. ribicola*.

SUMMARY

(1) A simple method for the use of safranin and lichtgruen in staining the mycelium of *Cronartium ribicola* and the cells of the host, *Pinus strobus*, is given in detail.

(2) The two stains employed give permanent preparations which are particularly favorable for the study of the relation of host to parasite.

(3) The mycelium of *C. ribicola* is distinguished from that of other fungi parasitic on white-pine bark by the size of the hyphæ and the possession of haustoria.

(4) The manner in which the parasite attacks the host cells is described in detail. This method of attack is characteristic of the blister-rust in white-pine bark.

(5) The presence in the bark of *P. strobus* of mycelium such as has been described is sufficient evidence to warrant the conclusion that the pine is infected with *C. ribicola*.

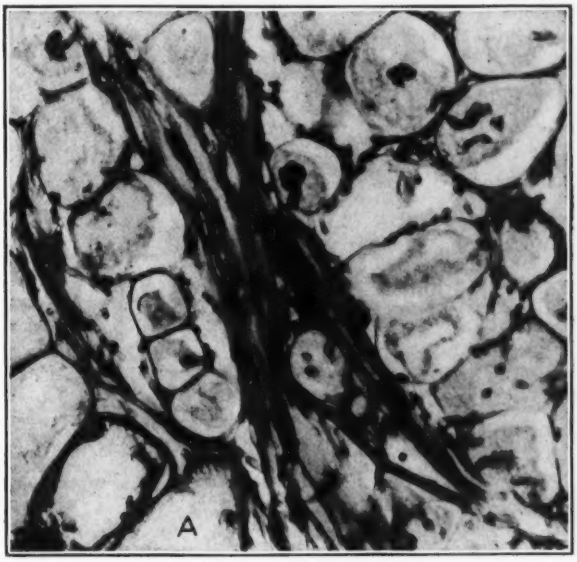
PLATE 31

Cronartium ribicola:

A.—A tangential section showing strands of hyphæ among the white-pine host cells. Note the haustoria. In the upper left-hand corner a haustorium can be seen denting the host nucleus. × 325.

B.—A haustorium showing the characteristic bend and irregular outline. The section just missed the connection of the haustorium with the hypha outside the cell. The host nucleus was torn by the razor. × 1,250.

These figures illustrate excellently the relation of the parasite to the host in the phloem parenchyma. Photomicrographs by the writer.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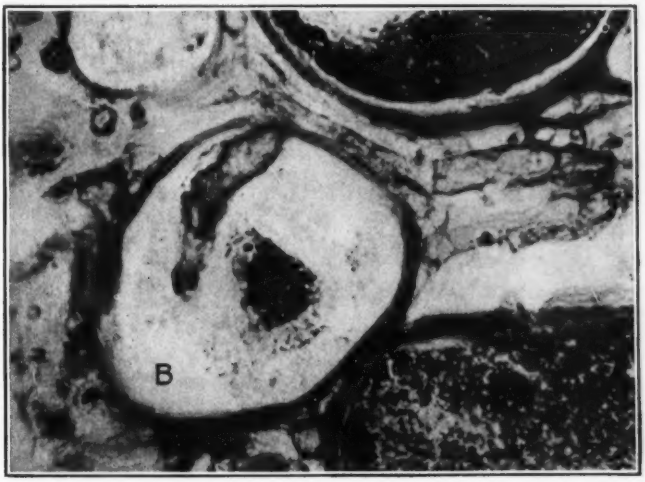
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